126-1

SUPREME COURT OF THE UNITED STATES,

OCTOBER TERM, 1886.

THE MOLECULAR TELEPHONE COMPANY et al., *Appellants,*

vs.

THE AMERICAN BELL TELEPHONE COMPANY, *Respondent.*

No. 667.

Testimony of Rudolph Messel et al., and Testimony of Prof. Chas. R. Cross, read by stipulation from the case of The American Bell Telephone Company vs. The New Jersey Telephone Company.

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U. S. Circuit Court,

DISTRICT OF NEW JERSEY.

AMERICAN BELL TELEPHONE CO. ET AL.

AGAINST

NEW JERSEY TELEPHONE CO. ET AL.

Upon the request of the defendants and Grosvenor Lowrey, Esq., counsel for other parties who are or may be in litigation against the American Bell Telephone Company, it is agreed as follows:

Commissions to take testimony on behalf of the defendants and others engaged in litigation against the American Bell Telephone Company may issue upon interrogatories and cross-interrogatories filed in the above cause as follows:

To Thomas M. Waller, of London, England, to take testimony of Dr. Rudolph Messel, of London, England.

To Albert Loenig, of Bremen, Germany, to take testimony of Philip Schmidt, of Wilhelmshaven, Germany.

To Jacob Mueller, or Alvesto S. Hogue, of Frankfort, Germany, to take testimony of Leon Garnier, of Friedrichsdorf, Germany.

To Jacob Mueller, or Alvesto S. Hogue, of Frankfort, Germany, to take testimony of Heinrich Hold, of Friedrichsdorf, Germany.

To Jacob Mueller, or Alvesto S. Hogue, of Friedrichsdorf, Germany, to take the testimony of Prof. C. Bohn, of Aschaffenburg, Germany.

To Alvesto S. Hogue, of Frankfort, Germany, to take the testimony of Prof. George Quincke, of Wasselheim, Germany.

To Alvesto S. Hogue, of Frankfort, Germany, to take the testimony of T. Hausser, of Wasselheim, Germany.

It is further stipulated that Rockwell Kent, Esq., may be employed as messenger to convey said commissions to the respective commissioners; that when executed the same may be sealed and returned by the commissioners, either through the hands of said Rockwell Kent or by mail addressed to the Clerk of the Circuit Court of the United States, District of New Jersey, N. J., U. S. A.

In case any commissioner named in any of the commissions cannot conveniently act, Mr. Kent may, in writing, appoint a substitute, giving in said writing the reason why the commissioner originally appointed cannot act; and such substitute commissioner shall have all the powers belonging to the commissioner originally named.

It is further stipulated that every objection to the competency or materiality of the questions or the answers contained in, or taken by or under any said commission be reserved to the same effect as if made on an application for the respective commissions, or to the respective interrogatories on the settlement thereof.

It is also understood and agreed that the commissions containing the interrogatories and cross-interrogatories shall be sealed by the Clerk of the Court; that the contents and nature of the cross-interrogatories shall not be made known to Mr. Kent; and that he shall not converse with the witnesses, or any of them, on the subject of their depositions, except for the purpose of arranging a meeting between them and

the commissioner for the execution of the commissions; that the interrogatories and the cross-interrogatories shall not be made known to the witnesses, or either of them, except by reading each in its order to the witnesses at the time the deposition is taken, and no interrogatory or cross-interrogatory is to be read to the witness until the preceding one has been answered; and no one except the commissioner, or a clerk to be employed by him to write the answers and named by him in his return shall be present while the depositions are being taken. The Clerk of the Circuit Court issuing the commissions shall specially call the attention of the commissioners to his duties in this respect.

It is also agreed that all the testimony taken under these commissions may be introduced into the record of the telephone cases in the Supreme Court on appeal in such manner as any Court may permit, the American Bell Telephone Company consenting to any form of procedure convenient for that purpose; but such admission or rejection or use is not in any way to involve the United States or affect the next stipulation herein.

In consideration that the United States shall pay a part of the expenses of taking the testimony under this commission, the American Bell Telephone Company, for itself, its successors or assigns, by its officers and lawfully authorized agents, hereby agree and stipulate that any testimony taken in this case in pursuance of the commissions or letters rogatory referred to in this stipulation may be used as evidence for the plaintiff in any suit lawfully brought, or which may hereafter be brought by the United States or any officer thereof, in behalf of the United States to cancel or annul any or every patent issued by the United States and claimed or owned by said company, either in its own right directly or by assignment or any other form of conveyance, with the same force and effect, and no other, as though said testimony had been regularly taken in such suit brought or which may hereafter be brought. But it must be

distinctly understood that the American Bell Telephone Company does not admit that any of the testimony proposed to be taken under the said commissions is legally competent or material in any suit, irrespective of the manner in which it is taken; it does not admit that it can be held in any district except the District of Massachusetts; it does not admit that any litigation respecting the Bell patent can be carried on in its absence; it does not admit that the Attorney-General has any authority whatever to bring a suit questioning the validity of the patent; and it does not waive any of its objections now taken, or hereafter to be taken, in any of these respects.

DICKERSON & DICKERSON,
Solicitors for Complainants, The American Bell Telephone Company,
By W. H. FORBES, President.
EDWARD N. DICKERSON,
JAMES J. STORROW,
Of Counsel for A. B. T. Co.
G. A. JENKS,
Solicitor-General, Acting Attorney-General of the United States in this matter.
WHEELER H. PECKHAM,
Solicitor for Defendant Molecular Telephone Company and others.
GROSVENOR LOWREY.
SAM'L A. DUNCAN,
Solicitor for Defendant.

CONSULATE GENERAL OF THE UNITED STATES OF AMERICA AT LONDON, ENGLAND.

Deposition of Rudolph Messel, a witness produced, sworn and examined on the 17th day of December, 1886, at the offices of the Consulate-General of the United States of America, situate No. 12 Saint Helen's Place, Bishopsgate street, in the City of London, England, aforesaid, by Thomas M. Waller, Consul-General of the United States at London, England, under and by virtue of a commission issued out of the Circuit Court of the United States for the District of New Jersey, in the City of Trenton and State of New Jersey, in a certain cause therein depending and at issue between American Bell Telephone Company et al., complainants, vs. New Jersey Telephone Company et al., defendants, as follows: Rudolph Messel of 36 Mark Lane, in the City of London, aged 38 and upwards, manufacturing chemist, being duly and publicly sworn pursuant to the directions hereto annexed and examined on the part of the defendants doth depose and say as follows:

Int. 1. Please state what is your name, age, residence and occupation?

To the first interrogatory he saith: My name is Rudolph Messel, I am 38 years old and upwards, my profession is that of a manufacturing and scientific chemist. I reside in London, my office being at No. 36 Mark Lane. I am a partner in the firm of Chapman, Messel & Company.

Int. 2. Were you acquainted with the late Philipp Reis, of Frankfort, Germany?

To the second interrogatory he saith: Yes, I knew Philipp Reis.

Int. 3. If to the last interrogation you answer yes, state, if you know, what was the occupation of the said Reis during the years 1859 to 1874, inclusive, or during any portion of that period in which you had knowledge of the matters now inquired about.

To the the third interrogatory he saith: I did not know him before 1860. I was a pupil in a school in which Mr. Reis was a master; for about two or three years, in Friedrichsdorf, to the best of my knowledge and belief, and went there in the fall of 1860, and continued as such pupil until the spring of 1863. I have no memorandum with me to verify my statement with regard to the years. The school record would, of course, show this conclusively. I met Mr. Reis occasionally after I left the school in Frankfort, at no time later than 1866. Mr. Reis, all the time I knew him, continued as master in the school I have named. I don't know the questions that will be afterwards asked me.

Int. 4. Do you know whether the said Reis was engaged during that period, or at any portion of that period in experiments having in view the transmission of articulate speech or other sounds by means of electricity. If you answer yes, and that he was so engaged in respect to either or both the subjects named, please state how you know the fact?

To the fourth interrogatory, he saith: Yes, I do. I was personally present often while he was so experimenting, and aided him as a boy of my age might. I made some parts with my own hands—for instance, an orifice.

Int. 5. Were you during the period above named ever present when the said Reis or any other person in his presence experimented with any apparatus in transmitting or attempting to transmit speech or other sounds. If you shall answer yes, please state on how many occasions, if more than one, at what time or times and place or places, as nearly as you can remember. Please answer this question as to any occasion when in the absence of said Reis such experiments were made by other persons by means of any instruments referred to in the 7th interrogatory?

To the fifth interrogatory, he saith: I do not know what particular instrument is meant by the question in

this case, although the question seems to presume so. I know of several instruments with which Mr. Reis made such experiments as are mentioned in the question, during the time I was his pupil. I remember that after I left the school I saw Mr. Reis in Frankfort at the place of Mr. Albert, a scientific instrument maker. Mr. Reis had an instrument there with him, but whether he experimented there upon it I do not recollect. I afterwards saw him in Frankfort in 1863 or 1864. I recollect no experiment at which Mr. Reis was not present and directing. At most of these experiments Philip Schmidt, a relative of Mr. Reis, was present. He usually talked into the instrument. Ernest Horckheimer—Küster, from Hanau, my brother, Ludwig Messel, and Mr. Peter, a musical master, were present on different occasions when experiments were made; and at some of the experiments the whole class would be present, consisting of from ten to twenty-five boys. All of the experiments to which I have alluded took place at the house of Mr. Reis.

Int. 6. If in answer to the last interrogatory you shall have named any occasion or occasions such as are in that interrogatory referred to, please state the names of all persons present on each occasions, as nearly as you can remember, and the character and results of the experiments then carried on, and especially the results thereof, so far as they related to the transmission of articulate speech or other vocal sounds, or to the transmission of sounds other than vocal sounds, and particularly whether any articulate words, spoken or sung, were sent and received, and the words or sentences, so far as you can remember them, and whether such words or sentences as you may give were all which were so sent and received?

To the sixth interrogatory, he saith: In answer to previous interrogatory I have stated the occasions when the experiments took place, and the persons who were present and took part in them, to the best of my recol-

lection. I recollect distinctly many attempts to transmit articulated speech, by the instrument used by Mr. Reis, with unequal results. Sometimes words and sentences would be transmitted distinctly; at other times the instrument failed to work and words and sentences would be imperfectly transmitted; sometimes one or two words of a sentence would be clearly transmitted and occasionally the instrument would transmit no words or sounds. I distinctly recollect experiments of singing into the instrument; the transmission of musical sounds were usually much better given than ordinary sounds of speech. Mr. Reis had two or three songs which were favorite songs to the instrument. I recall the names of some of the songs:

(*a*) "Wer will unter die Soldat—"
(*b*) "Ich hatt 'einem Kameraden—"
(*c*) "Letzte Rose—"

I recollect that one of the musical instruments used was an instrument having organ pipes; and other instruments were also used. There was a difficulty experienced in some of these experiments, from the nearness of the direct sounds. Usually the receiver was in the front of the house, and the sounds were transmitted through the house and through a yard into a room at the back of a yard, a distance of about 100 feet. In all cases where the instrument worked at all, a person reading a book at the transmitter would be understood at the receiver—that is, a person with a copy of the book used at the receiver could easily distinguish and follow the sentences. All the sentences used were usually short ones, and these could be frequently understood without the assistance of a book. Exclamations in German like Halt! Who goes there? in English, could be always understood. The facility of understanding words depended largely upon the loudness of the voice and character of the voice and length of the sentence. A high voice, such

as boys have, was the most easily understood. A screaming sound in the instrument would produce a loud noise but without articulation.

Int. 7. Look at the pictatorial representations hereunto annexed and marked , and state whether you recognize in any of them representations of instruments used in any experiments to which you may have testified for the transmission of speech or other sounds by electricity; and if you answer yes, state which of the drawings you so recognize, and say whether, according to your recollection, such drawings accurately show such instruments, or, if any of them differ in any way, wherein they differ. If you say that none of the instruments shown in these pictatorial representations were used, please describe as nearly as you can the instruments actually used in the experiments concerning which you may have testified?

To the seventh interrogatory, he saith: I have looked at the illustrations. The only instruments I recollect having been used in the experiments to which I have testified, are the instruments similar to the following:

1B or 3c, for I cannot distinguished any difference between them in principle, and 2A and 5A. There were several instruments used like 5A, but their connections were different. Instruments were experimented with similar to 5A, but where the membrane was put in a horizontal and not in a vertical position, in some cases the membrane pointing upwards and in others pointing downwards. I have only a distinct recollection of the latter instrument as it differed completely from those previously used, having a single point fixed to the membrane which just touched a very small cup containing mercury or some other fluid. What it was I do not know. This latter instrument seemed very promising. I recollect it on account of its simplicity, but cannot give details of the results of its working. There were other instruments used, and as a rule the knitting needle was placed upon the resonator. I cannot recol-

lect any experiment where it was not so placed. Sometimes a violin was used as a resonator; sometimes an empty box. Some of the instruments in use, if the current were interrupted, emitted sparks at the receiver. This, I recollect, Mr. Reis considered highly objectionable and tried to avoid it. Mr. Reis experimented with quite a number of instruments varying in detail but all embodying the same principle, being of the same type as 2A or 5A.

Int. 8. If you shall have answered that you were ever present at experiments such as are referred to in the 5th, 6th, and 7th interrogatories, and that articulate speech or any vocal sounds were transmitted, state whether entire sentences were transmitted and received, or only single words, and state also, if you can, what sentences or words then spoken or sung were heard by you at the receiver, and what, if any, were reported by others then listening at the receiver?

Explain for the information of the Court the respective position of the transmitting and receiving instruments, your position with reference to each, and your position with reference to any person who reported any words or sentences spoken or sung as having been received?

To the eighth interrogatory, he saith: I think I have already answered this question in detail. I may add, however, that I have myself heard the words of the songs I have named, at the receiver, and sentences and readings there. I cannot recall the sentences nor name the book from which I heard the readings. As I recollect I believe it was a book of military instructions. I have already stated the position of the instrument at the time of the experiments and have testified to only what I saw myself with regard to the sparks, and what I heard myself at the receiver, or spoke myself at the transmitter. I have testified to nothing based upon other people's reports upon the instruments or about the experiments, except as to the report of the person

at the transmitter of what I spoke at the receiver, or at the receiver what I heard at the transmitter.

Int. 9. State also if you saw the said Reis use any water or other fluid in or about his apparatus, or any part thereof, and particularly how the same was used, and for what purpose, if you know?

To the ninth interrogatory he saith: I have already stated that in some of the experiments he used mercury or some other liquid. I don't remember that Mr. Reis ever stated why he used mercury or any other liquid.

Int. 10. Do you know or can you set forth any other matter or things which may be a benefit or advantage to the parties at issue in this cause, or either of them, or that may be material to the subject of this your examination or matters in question in this cause. If yea, set forth the same fully and at large in your answer?

To the tenth interrogatory he saith: I know that Mr. Reis' purposes were to complete an instrument for the transmission of articulated speech, and that he recognized its defects and the reasons for them.

The complainants object to the direct interrogatories, as follows:

To the Fourth Int. Objected to as incompetent and irrelevant; because it is of no importance in law what Philipp Reis may have done in Germany, or other foreign countries, unless Mr. Bell's invention or discovery had been patented or described in some printed publication.

To the Fifth Int. Same objection.

To the Sixth Int. Same objection.

To the Seventh Int. Same objection.

To the Eighth Int. Same objection; and further

because the last paragraph is leading, and calculated to instruct the witness to describe an operation which neither Reis nor any other person who ever saw his telephone ever described in any publication, or suggested, even when Reis himself gave the most ample explanations of his apparatus and its operation.

DICKERSON & DICKERSON,
Complainants' Solicitors.
By J. J. S.

CROSS-INTERROGATORIES.

x-Int. 1. In what year were you born; and what is your profession or occupation?

To the first cross-interrogatory he saith: I was born January 4th, 1848. I received the degree of Ph. D. at the University of Tübingen. I am at present a chemical manufacturer in London.

x-Int. 2. Are you the same person who wrote a letter to Professor Sylvanus P. Thompson, dated April, 1883, and published in the book entitled "Philipp Reis, Inventor of the Telephone?"

To the second cross-interrogatory he saith: Yes.

x-Int. 3. Do you know anything more now about what Reis did than when you wrote that letter?

To the third cross-interrogatory he saith: No, but I may not have put all I knew about what Reis did in that letter. I have not that letter with me in this office to refer to.

x-Int. 4. Were you not a schoolboy at the Garnier Institute, between 1860 and 1862, when you think you saw what you have stated about Reis and his telephone?

To the fourth cross-interrogatory he saith: Yes.

x-Int. 5. In that letter you state: "I was, however,

very young, and am sorry that much that I then saw and heard has been forgotten." Is not that true?

To the fifth cross-interrogatory he saith: Yes.

x-Int. 6. Under what circumstances did you write that letter?

To the sixth cross-interrogatory he saith: Professor Thompson asked me what information I could give him, and in response I wrote the letter, and was anxious to state all I knew for the honor of Mr. Reis, my tutor and friend.

x-Int. 7. Did Prof. Thompson inform you that he was employed by persons charged as infringers of patents for the telephone, and that he was making up a book in their interest to aid in their defense?

To the seventh cross-interrogatory he saith: No.

x-Int. 8. Have you not seen a Mr. Stetson, from the United States, on the subject?

To the eighth cross-interrogatory he saith: No; I have seen no person, and no person has seen me in regard to any lawsuit.

x-Int. 9. Did he not inform you that he was employed by the Government of the United States to assist in proving that Reis, and not Bell, was the inventor of the telephone; or had you not heard that such was his purpose?

To the ninth cross-interrogatory he saith: No; but Mr. Thompson asked me last summer (1886) if I was prepared to go to the United States to testify what I knew about the Reis telephone. He said that the American Government desired information about the Reis telephone, and I told him that I had other engagements and would not like to go.

x-Int. 10. State fully what he did inform you as to his employment and his object in seeing you?

To the tenth cross-interrogatory he saith: As I have said before, Mr. Stetson never saw me.

x-Int. 11. You say in that letter: "We had a book, and were to find out what part of the page the reader

was just transmitting. We frequently used a sort of 'Exercier Reglement'—a soldier's instruction book, or something of that kind." Who do you refer to by the word "we"?

To the eleventh cross-interrogatory he saith: Mr. Reis, Philip Schmidt, his brother-in-law, and myself.

x-Int. 12. Is not this the performance which you intend to describe, namely, a person was reading a book at one end of the line, and others were at the other end with a similar book, following the reader as the words were delivered to them by the receiver?

To the twelfth cross-interrogatory he saith: Yes; of course it is, although I cannot say whether the man at the other end had a book or extracts from a book. I could not see him.

x-Int. 13. Describe just how these readings, which you say were frequently performed, were done. Who was the reader and who were the listeners? In what place was the transmitter, and in what the receiver. Did the listeners stand around the table where the instrument was, or were they seated? Were these a part of school exercises or only done on holidays?

To the thirteenth cross-interrogatory he saith: Philip Schmidt at one end usually read or spoke or sang. Sometimes I did. Usually, when the experiment was a transmission of words, sentences and singing, when no instrument was required, the transmitter was in a small house at the back of the garden of Mr. Reis' house, and the receiver was in the large room next to the physical cabinet in the front of Mr. Reis' house. The transmitter and receiver were about one hundred feet apart, as I have said before. The listeners stood around the table where the instrument was. There were three classes of experiments—one to the class, one to three or four of the pupils who received private lessons from Mr. Reis—Horckheimer, Küster, Schmidt and myself—and the third on occasions when I was alone with him and P.

Schmidt in these experiments. No experiments ever took place on holidays.

x-Int. 14. You say that "To make matters worse, the early transmitter had no adjusting screws, and the contact was only regulated by a piece of bent wire, and the hammer was fixed to the membrane." How did you find out that these peculiarities "made matters worse." Did Reis tell you at the time that these were defects or did you discover it for yourself?

To the fourteenth cross-interrogatory he saith: I knew that these things made matters worse, because other experiments of Mr. Reis remedied them. I don't know whether I discovered them myself or Mr. Reis told me of them. I don't remember.

x-Int. 15. As you understand it, when Reis made the operative parts of his instruments himself, after 1862, when you left the school, and when he had them made for sale by Albert, to whom you refer; did he apply the "adjusting screw" to the instrument, and so remedy the defect; and if so, can you refer to any description of any of the perfected instruments on sale to the public either by Albert or others in which the defects before 1862 were remedied?

To the fifteenth cross-interrogatory he saith: My knowledge of instruments made by Mr. Reis after 1862 or 1863, after I left Friedrichsdorf, is derived from seeing instruments said to be made by him, and through published illustrations of instruments said to be made by him. I know some of Reis' instruments made after 1862 (1862) had an adjusting screw. I don't know whether this screw remedied the previous defects or not.

x-Int. 16. In your letter you say in respect to one of the instruments which you think you remember, when you were a schoolboy, twenty or more years before, that "The apparatus started off with splendid results, but may probably have been abandoned on account of its great uncertainty, thus sharing the fate of

others of his earlier instruments." Which were the other instruments he abandoned, and which were those he brought to perfection, as you suppose ?

To the sixteenth cross-interrogatory he saith: He seems to have abandoned all his earlier forms, and endeavored to perfect the instrument in the forms in which it is now known as Reis' telephone.

x-Int. 17. In your letter you say: "I am sorry that owing to the lapse of time, I am unable to throw more light on Reis' original labor in a field of physical science which promised so much for the future; but insufficient as are my recollections, they may not be without public interest, and at any rate I am glad of this opportunity of offering my humble tribute of regard and affection to the memory of my old teacher and friend." Does that represent your present state of mind on the subject ?

To the seventeenth cross-interrogatory he saith: It does.

x-Int. 18. In your letter you say that one form of instrument was "one which Reis based great hopes upon. The instrument was very rough, however, consisting of a wooden bung of a beer barrel (which I had hollowed out for an earlier telephone—it was not turned inside like others), and this we closed with a membrane. The favorite 'Hämmerchen' was replaced by a straight wire, fixed in the usual way with sealing-wax, and the apparatus stood within a sort of tripod, membrane downwards, the pin just touching the surface of a drop of mercury contained in a small cup forming one of the terminals of the circuit. The apparatus started off with splendid results, but may probably have been abandoned on account of its great uncertainty, thus sharing the fate of other of his earlier instruments." This statement is accompanied by a sketch as follows:

Is there any published account of this experiment before 1876, that you know of; and if you say there is, name it and annex a copy ?

To the eighteenth cross-interrogatory he saith: I am not aware of any published accounts, and this is the reason why I called attention to it.

x-Int. 19. Was not this form superseded by better forms before the exhibition of Reis in 1861?

To the nineteenth cross-interrogatory he saith: I cannot say, but I am sure this other instrument was used after 1861.

x-Int. 20. If you should say that Reis used water in his transmitter, will you explain how he prevented it from wetting the stretched membrane and destroying its elasticity?

To the twentieth cross-interrogatory he saith: I only know of the use by Reis of some sort of liquid. I cannot say what it was. This liquid was placed as shown in drawing by me made on Exhibit A, and I don't see how it could possibly touch the membrane.

x-Int. 21. Did you ever see any published account by Reis, or any other experimenter, of the use of water at the contact points of the telephone for any purpose; and if so, in what publication did you see it, and annex a copy of it?

To the twenty-first cross-interrogatory he saith: I never saw any such publication.

x-Int. 22. Isn't it certain that if water were applied at the contact point, it would be scattered at once by the vibration of the membrane and wet it, and also be decomposed by the current of electricity passing through it at that point?

To the twenty-second cross-interrogatory he saith: I never made the experiment.

x-Int. 23. Who first spoke to you on the subject of water used by Reis to operate his telephone?

To the twenty-third cross-interrogatory he saith: No person ever spoke to me about it, to the best of my recollection, and I don't know that he used water. I have not undertaken to state what the liquid was. I don't know.

x-Int. 24. Have any of these questions been shown to you, or have you read, or heard read, any of them, or have their contents or effect been stated to you by any person before they were propounded to you on the examination one by one, and answered by you?

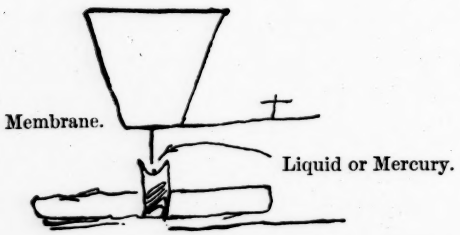
To the twenty-fourth cross-interrogatory he saith: No; I read the questions in German, one by one, and did not see any question until the previous ones had been answered by me. The questions in English were so read to me and so answered by me.

Examination taken, reduced to writing, and by the witness subscribed and sworn to this 17th day of December, 1886, before me.

RUDOLPH MESSEL,
Commissioner.

[L. S.]

Exhibit A. No. 1.



At the execution of a commission for the examination of witnesses between American Bell Telephone *et al.*, Complainants, vs. New Jersey Telephone Co, *et al.*, Defendants, this exhibit numbered 1, and hereto annexed, was produced and shown to Rudolph Messel, and by him deposed unto, and subscribed by him at the time of his examination before Thomas M. Waller, Commissioner.

Names of parties in this suit not filled out when I signed this, nor do I know who they are. My signature stands only for above sketch.

RUDOLPH MESSEL,
Witness.

17 | 12 | 86.

KINGDOM OF GREAT BRITAIN AND IRELAND,
City of London, England.

I, THOMAS M. WALLER, Consul-General of the United States of America, at London, England, do hereby certify that Rudolph Messel, the witness, personally appeared before me at my office, No. 12 Saint Helen's Place, Bishopsgate street, in the City of London, England, on the 17th day of December, 1886, and after being duly sworn to testify the truth, the whole truth and nothing but the truth, did depose to the matters contained in the foregoing deposition, and did in my presence subscribe to the deposition and endorse the exhibit to which he testified. And I further certify that I have subscribed my name to each half sheet and to the exhibits. I also further certify that said deposition was carefully reduced to writing by Alfred Nutting, a disinterested person, appointed by me as clerk for that purpose.

In witness whereof I have hereunto set my hand and affixed my official seal, at London aforesaid, this 18th December, 1886.
(Signed) THOMAS M. WALLER,
Commissioner.

Deposition of Philipp Schmidt, a witness, produced, sworn and examined the fourteenth day of December, in the year one thousand eight hundred and eighty-

six, at Bremen in the Empire of Germany, under and by virtue of a commission issued out of the Circuit Court of the United States for the District of New Jersey, in a certain cause therein depending and at issue, wherein the American Bell Telephone Company and others are plaintiffs, and the New Jersey Telephone Company and others are defendants.

PHILIPP SCHMIDT, of Wilhelmshaven, Germany, paymaster in the Imperial German Navy, aged 39 years and upwards, being duly and publicly sworn, pursuant to the directions hereto annexed and examined on the part of the defendants, doth depose and say as follows :

Int. 1. Please state what is your name, age, residence and occupation ?

FIRST. To the first interrogatory he saith :

Mein Namen ist Johann Philipp Schmidt, ich bin 39 Jahre alt, ich bin Zahlmeister der Kaiserlich-Deutschen Marine, und zu Wilhelmshafen ansässig.

My name is Johann Philipp Schmidt ; I am 39 years old, Paymaster in the Imperial German Navy, and I live at Wilhelmshafen.

Int. 2. Were you acquainted with the late Philipp Reis, of Frankfort, Germany ?

SECOND. To the second interrogatory he saith :

Ich war mit dem verstorbenen Philipp Reis bekannt, er war mein Schwager.

SECOND. To the second interrogatory he saith : I was acquainted with the late Philipp Reis ; he was my brother-in-law.

Int. 3. If to the last interrogation you answer yes, state if you know, what was the occupation of the said Reis during the years 1859 to 1874, inclusive, or during any portion of that period in which you had knowledge of the matters now inquired about ?

THIRD. To the third interrogatory he saith :

Philipp Reis war Lehrer an der Lehranstalt Garnier zu Friedrichsdorf, bei Frankfurt a-M. Ich wohnte in

seinem Hause daselbst von 1859 bis 1864, beide Jahre eingeschlossen. Ph. Reis war Lehrer der französischen Sprache, der Physikund Chemie zu jener Zeit. Er beschäftigte sich in seinem Hause sehr viel mit physikalischen Experimenten, und construirte in den oben bezeichneten Jahren einen Apparat, den er mit dem Namen Telephon bezeichnete. Ich experimentirte selbst mit, und half meinem Schwager Reis bei seinen Versuchen.

THIRD. To the third interrogatory he saith: Philipp Reis was teacher in the Garnier Institute, at Friedrichsdorf, near Frankfort-on-the-Main. I lived at his house in that place from 1859 to 1864, both years included. Philipp Reis was at that time teacher of the French language, physics, and chemistry. He was occupied very much at home with physical experiments, and he constructed in the above-mentioned years an apparatus which he called telephone. I myself experimented with and helped my brother-in-law Reis in his experiments.

Int. 4. Do you know whether the said Reis was engaged during that period, or at any portion of that period, in experiments having in view the transmission of articulate speech, or other sounds, by means of electricity. If you answer yes, and that he was so engaged in respect to either or both of the subjects named, please state how you know the fact?

FOURTH. To the fourth interrogatory he saith:

Ja. Die Beantwortung dieser Frage ergiebt sich aus der Beantwortung der letzten Frage. Es wurde durch Philipp Reis mit der Transmission von artikulirter Sprache und anderen Töne vermittelst Electricität experimentirt. Ich habe dabei meistens als Sprecher fungirt und musste mir einfallende Sätze in den Sende-Apparat hineinsprechen, wie z. B., " Guten Morgen, Herr Fischer," " Das Pferd frisst Gurkensalat," u. a. m. Nach einem solchen Versuch hat Herr Ph. Reis diese Sätze mir wiederholt, zum Beweise, dass er sie vermittelst des Ap-

parates wohl verstanden und vernommen habe. Die Experimente fanden statt aus einem geschlossenen Raum im Wohnhause von Ph. Reis in Friederichsdorf nach einem geschlossenen Raum in der Scheune, jenseits des Hofes des Wohnhauses belegen. Die Entfernung kann ich nicht genau angeben, sie mag vielleicht ungefähr 50 Meter oder mehr vom Sende-Apparat zum Sprech-Apparat gewesen sein. Die Versuche fanden abwechselnd zwischen uns statt, d. h. Philipp Reis sprach in den Sende-Apparat und ich hörte seine Worte am Sprech-Apparat, oder ich sprach, was meistens der Fall sein musste, u. mein Schwager Reis lauschte am Sprech-Apparate auf meine Worte, die wir zur Controlle später gegenseitig austauschten. Ph. Reis lauschte meistenteils am Sprecher-Apparat, um die Leistungsfähigkeit desselben zu erproben, Fehler zu entdecken, u. Verbesserungen an demselben zu ersinnen.

FOURTH. To the fourth interrogatory he saith: Yes. The answer to this question is included in the answer to the last question. Experiments in the transmission of articulate speech and other tones by means of electricity were made by Philipp Reis. I was in these experiments mostly occupied as speaker, and had to speak into the transmitter casual sentences, as for example, "Good morning, Mr. Fisher," "The horse eats cucumber salad," etc. After such an experiment Mr. Reis would repeat to me these sentences to show that he had, by means of the apparatus, heard and recognized them. The experiments took place between a closed room in the dwelling house of Philipp Reis in Friedrichsdorf, and a closed room in the shed situated across the court of the dwelling house. I cannot give the exact distance; it was perhaps about fifty metres or more from the transmitter to the receiver. The experiments took place alternately between us, that is, Philipp Reis spoke into the transmitter and I heard his words at the receiver, or I spoke, which was generally the case, and my brother-in-law Reis listened

at the receiver to my words; these we afterward compared together. Philipp Reis listened mostly at the transmitter in order to test the efficiency of the apparatus, to discover faults and to contrive improvements in the apparatus.

Int. 5. Were you, during the period above named, ever present when the said Reis, or any other person in his presence, experimented with any apparatus in transmitting or attempting to transmit speech or other sounds. If you shall answer yes, please state on how many occasions, if more than one, at what time or times and place or places, as nearly as you can remember. Please answer this question as to any occasion when in the absence of said Reis such experiments were made by other persons by means of any instruments referred to in the 7th interrogatory?

FIFTH. To the fifth interrogatory he saith:

Ja, ich war häufig zugegen, wie sich das aus meinen bisherigen Antworten ergiebt. Die Versuche fanden wiederholt und an verschiedenen Tagen und Jahreszeiten statt, weil das Bestreben meines Schwager Reis darauf hinausging, seine Erfindung zu vervollkommnen. Diese Versuche fanden statt in den Jahren 1859 bis 1864, und zwar im Hause von Ph. Reis in Friederichsdorf. Derselbe hat seine Erfindung im Physikalischen Verein zu Frankfurt a. M. durch einen Vortrag erläutert, seinen Apparat gezeigt, und in Thätigkeit gesetzt, wobei ich den Sprecher abgab. Der Raum, wo der Vortrag statt fand, und wo der Sprech-Apparat sich befand, wurde von mir gar nicht betreten. Der Raum, in welchem ich mit dem Sende-Apparat mich befand—so glaube ich zu erinnern—lag in einem anderen Hause, als der Zuhörer Raum, und führte die Leitung des Apparates durch einen Garten. I glaube der Vortrag fand im Jahre 1863 statt. Einen ähnlichen Vortrag hielt Philipp Reis in demselben Jahre auf einer Naturforscher Versammlung zu Giessen. Den letzten Satz dieser Frage glaube ich dahin beantworten zu

können, dass ich mich nicht erinnere, dass in der Abwesenheit meines Schwagers Reis irgend einem Anderen gestattet gewesen sei, mit dem von Ph. Reis erfundenen Apparat Versuche anzustellen.

FIFTH. To the fifth interrogatory he saith: Yes; I was present, as already appears from my former answers. The experiments took place repeatedly, both on different days and different seasons of the year, because the object that my brother-in-law Reis had in view was to perfect his invention. These experiments took place in the house of Philipp Reis, in Friedrichsdorf, in the years 1859 to 1864. Reis, in a lecture before the Physikalische Verein of Frankfort-on-the-Main, described his invention, showed his apparatus, and put it in operation, I being the speaker at the transmitter. I did not enter the room where the lecture took place, and where the receiver was. The room in which I was stationed with the transmitter, as near as I can remember, was in a separate house from the lecture room, and the connecting wire of the apparatus passed through the garden. I think the lecture took place in the year 1863. Philipp Reis delivered a similar lecture in the same year before the Assembly of Natural Scientists at Giessen. To the last sentence of this question I think I can answer that I do not remember, that in the absence of my brother-in-law Reis, any person whatever was allowed to experiment with the apparatus invented by Philipp Reis.

Int. 6. If, in answer to the last interrogatory you shall have named any occasion or occasions such as are in that interrogatory referred to, please state the names of all persons present on each occasion, as nearly as you can remember, and the character and results of the experiments then carried on, and especially the results thereof so far as they related to the transmission of articulate speech or other vocal sounds; or to the transmission of sounds other than vocal sounds, and particularly whether any articulate words, spoken or sung, were

sent and received; and the words and sentences, so far as you can remember them, and whether such words or sentences as you may give were all which were so sent and received?

SIXTH. To the sixth interrogatory he saith:

Ich kann Ihnen keine Personen nahmhaft machen, welche den Vorträgen und Versuchen von Ph. Reis im Physikalischen Verein zu Frankfurt a. M., oder auf der Naturforscher Versammlung zu Giessen beiwohnten, da ich den Zuhörer-Raum nicht betreten habe. Ich musste bei dem Sende-Apparat bleiben. Indessen bei den Versuchen in der Wohnung des Herrn Ph. Reis in Friederichsdorf, waren unter Anderen öfters zugegen die derzeitigen Lehrer an dem Lehr-Institut Garnier daselbst, namens Holt und Hausser. Andere waren zugegen, deren Namen ich mich nicht erinnere. Ich beziehe mich im übrigen auf die bereits gegebenen Antworten, die ich nur bestätigen kann. Ich sang z. B. die Melodien folgender Lieder: "Wer will unter die Soldaten," &c.; ferner, "Ich hatte einen Kameraden," &c., und "Morgenroth, leuchtest mich zum frühen Tod," &c., und andere Lieder durch den Sende-Apparat. Die Melodien wurden am Sprech-Apparat, wie mir versichert wurde, deutlich vernommen und verstanden. Viele andere Sätze und Lieder, als die von mir bereits bezeichneten, wurden gesprochen, resp. gesungen, doch kann ich mich nicht mehr aller erinnern.

SIXTH. To the sixth interrogatory he saith: I cannot mention by name any person who was present at the lectures and experiments of Philipp Reis in the Physikal Verein of Frankfort or the Assembly of Natural Scientists at Giessen, as I did not enter the lecture-room. I had to remain at the transmitter. But in the experiments at the house of Mr. Philipp Reis in Friedrichsdorf, there were, among others often present, Messrs. Holt and Hausser, at that time teachers at the Garnier Institute. There were others present whose names I cannot recall. For the rest I

refer to the answers already given, which I can confirm. I sang, for example, the melodies of the following songs, into the transmitter:

"Who will be a soldier," etc.; and "I had a comrade." "Morning dawn, thou lightest me to an early death," and other songs. The melodies were, as I was assured, clearly heard and understood at the receiver. Many other sentences and songs besides those already designated by me were spoken and sung, but I cannot now recall all of them.

Int. 7. Look at the pictorial representations hereunto annexed and marked , and state whether you recognize in any of them representations of instruments used in any experiments to which you may have testified for the transmission of speech or other sounds by electricity; and if you answer yes, state which of the drawings you so recognize, and say whether, according to your recollection, such drawings accurately show such instruments; or, if any of them differ in any way, wherein they differ. If you say that none of the instruments shown in these pictorial representations were used, please describe as nearly as you can the instruments actually used in the experiments concerning which you may have testified?

SEVENTH. To the seventh interrogatory saith:

Die vorliegenden, mit 1 A & 1 B bezeichneten Abbildungen eines Telephons sind Abbildungen des letzten von Ph. Reis verbesserten Apparates, dessen Ph. Reis sich bediente, als ich noch bei ihm wohnte. Die Zeichnung 1 A zeigt den Sende-Apparat u. 1 B den Sprech-Apparat. Die 2 A bezeichnete Abbildung scheint mir eine Zeichnung eines Apparates zu sein, wie ihn Ph. Reis benutzte, bevor er den besseren Apparat 1 A & 1 B sich angefertigt hatte. Die Abbildungen 3 A, 3 B und 3 C scheinen mir ebenfalls Apparate vorzustellen, wie Ph. Reis sie vor Benutzung von 1 A & 1 B erfunden hat. Ich kann mich der einzelnen Ausführung nach dieser Zeichnung nicht mit vollster Bestimmt-

heit entsinnen. Die Abbildungen 4 A & 4 B nöthigen mich zu einer gleichen Erklärung, es sind nach meinem Dafürhalten ebenfalls Apparate, die Ph. Reis benutzte, bevor er seinen letzten Apparat 1 A & 1 B erfunden hatte. Die Zeichnung-en 5 A & 5 B nöthigt mich zu einer ganz gleichen Erklärung, wie bei 4 A & 4 B. Ich glaube in den Zeichnungen 1 A & 1 B diejenigen Apparate wieder zu erkennen, die in dem Physikalischen Verein zu Frankfurt a. M., u. auf der Naturforscher Versammlung zu Giessen von Ph. Reis benutzt worden sind. Dieselben sind damals auch käuflich zu haben gewesen. Eine genaue Erklärung der von Ph. Reis successiven erfundenen Instrumente oder Apparate, Telephone von ihm benannt, ist mir nicht möglich, da bei den Jahren hindurch dauernden Versuchen ein häufiger Wechsel der Apparate, Verbesserungen u. Aenderungen an denselben statt fanden.

SEVENTH. To the seventh interrogatory he saith: The enclosed drawings of a telephone designated with 1A 1B are drawings of the latest improved apparatus which Philipp Reis used when I lived with him. The drawing 1A shows the transmitter and 1B the receiver. The drawing marked 2A appears to me to be a drawing of an apparatus such as Philipp Reis used before he had made his improved apparatus. The drawings 3A, 3B and 3C, appear to me also to represent apparatus that Philipp Reis had invented before using 1A and 1B. I cannot recall the separate details of this drawing with complete certainty. The drawings 4A and 4B require from me the same explanation. They are also in my opinion apparatus which Philipp Reis used before he had invented his last apparatus 1A and 1B. The drawings 5A and 5B require of me just the same explanation as 4A and 4B. I think that I recognize in the drawings 1A and 1B the apparatus which were used by Philipp Reis in the Physikal Verein at Frankfort-on-the Main, and at the Assembly of Natural Scientists at Giessen. The same are also to be had on sale. I can-

not give an exact description of the instruments or apparatus successively invented by Philipp Reis and called by him telephones, since, in the experiments, extending over a term of years, frequent changes of the apparatus, improvements and modifications were made.

Int. 8. If you shall have answered that you were ever present at experiments such as are referred to in the 5th, 6th and 7th interrogatories, and that articulate speech or any vocal sounds were transmitted, state whether entire sentences were transmitted and received, or only single words, and state also, if you can, what sentences or words then spoken or sung were heard by you at the receiver, and what, if any, were reported by others then listening at the receiver?

Explain for the information of the Court the respective position of the transmitting and receiving instruments, your position with reference to each, and your position with reference to any person who reported any words or sentences spoken or sung as having been received.

EIGHTH. To the eighth interrogatory he saith:

Diese Frage habe ich bereits durch die früheren Fragen zum grössten Theil erledigt. Ph. Reis hat häufig dieselben Redensarten benutzt, wie ich, wenn er am Sende-Apparat sprach u. ich am Sprech-Apparatt lauschte. Ich habe dann alles Gesprochene deutlich vernommen. Auf den zweiten Satz dieser Frage kann ich nur erwiedern, dass die Apparate auf Tischen standen, und die Sprechenden resp. Lauschenden vor den betreffenden Apparaten sassen auf Stühlen.

EIGHTH. To the eighth interrogatory he saith: This question I have already mostly answered in the former questions. Philipp Reis often used the same expressions as I when he spoke to the transmitter, and I listened at the receiver. On such occasions I clearly understood all that was spoken. To the second sentence of this question I can only answer that the ap-

paratus stood on tables and those speaking and listening sat in front of the respective apparatus in chairs.

Int. 9. State also if you saw the said Reis use any water or other fluid in or about his apparatus, or any part thereof, and particularly how the same was used, and for what purpose, if you know?

NINTH. To the ninth interrogatory he saith:

Ich habe nie bemerkt, dass Ph. Reis eine Flüssigkeit um seinen oder in seinem Apparat benutzt hat. Jedenfalls entsinne ich mich dessen nicht.

NINTH. To the ninth interrogatory he saith: I have never noticed that Philipp Reis used a liquid in or about his apparatus, at least I do not remember it.

Int. 10. Do you know, or can you set forth, any other matter or things which may be a benefit or advantage to the parties at issue in this cause, or either of them, or that may be material to the subject of this your examination or the matters in question in this cause. If yea, set forth the same fully and at large in your answer?

TENTH. Diese Frage muss ich verneinen.

TENTH. To the tenth interrogatory he saith: To this question I must answer no.

The complainants object to the direct interrogatories as follows:

To the Fourth Int. Objected to as incompetent and irrelevant; because it is of no importance in law what Philipp Reis may have done in Germany or other foreign countries, unless Mr. Bell's invention or discovery had been patented or described in some printed publication.

To the Fifth Int. Same objection.

To the Sixth Int. Same objection.

To the Seventh Int. Same objection.

To the Eighth Int. Same objection; and further, because the last paragraph is leading, and calculated to instruct the witness to describe an operation which neither Reis nor any other person who ever saw his telephone ever described in any publication, or suggested, even when Reis himself gave the most ample explanations of his apparatus and its operation.

DICKERSON & DICKERSON,
Complainants' Solicitors,
By J. J. S.

CROSS-INTERROGATORIES.

x-Int. 1. In what year were you born?

FIRST. To the first cross-interrogatory he saith:

Ich bin im Jahre 1847 geboren.

FIRST. To the first cross-interrogatory he saith: I was born in the year 1847.

x-Int. 2. What is your present occupation and how long have you been engaged in it?

SECOND. To the second cross-interrogatory he saith:

Ich bin Kaiserl-Deutscher Marine Zahlmeister und als solcher seit 1877 angestellt; in untergeordneter Stellung bin ich 1875 in die Marine Verwaltung eingetreten.

SECOND. To the second cross-interrogatory he saith: I am Imperial German Marine Paymaster, and as such employed since 1877. I entered the navy in a subordinate position in 1875.

x-Int. 3. What was your occupation and where did you reside from 1860 to 1864?

THIRD. To the third cross-interrogatory he saith:

Ich war Schüler in der Lehranstalt Garnier zu Friedrichsdorf, bei Frankfurt a. M. bis zum Jahre 1863, u. wohnte bei meinem Schwager Ph. Reis daselbst in der Zeit von 1859 bis 1864. Als ich die Schule verlassen

hatte, trieb ich Privat Studien, und wohnte bei meinem Schwager.

THIRD. To the third cross-interrogatory he saith: I was a scholar in the Garnier Institute at Friedrichsdorf, near Frankfort-on-the-Main, until the year 1863, and lived there with my brother-in-law, Philipp Reis, in the time from 1859 to 1864. After I left the school I took private lessons and lived with my brother-in-law.

x-Int. 4. When were you first asked to testify about the Reis machine, and by whom?

FOURTH. To the fourth cross-interrogatory he saith:

Gerichtlich wurde ich niemals aufgefordert, Zeugenschaft über die Reis'schen Apparate abzulegen.

FOURTH. To the fourth cross-interrogatory he saith: I was never legally summoned to give testimony in reference to the Reis apparatus.

x-Int. 5. Did not Mr. Stetson, of the United States, talk with you on the subject during the last year?

FIFTH. To the fifth cross-interrogatory he saith:

Herr Stetson hat mich zwei Male besucht, und über den Reis'schen Apparat befragt. Ich glaube, es war zuerst in 1884, und zuletzt in dem Frühjahr dieses Jahres, 1886. Herrn Stetson habe ich gleiche Erklärungen, wie heute, gegeben, soweit ich mich dessen erinnern kann. Zeichnungen oder Abbildungen von Telephon-Apparaten hat derselbe mir nicht vorgezeigt.

FIFTH. To the fifth cross-interrogatory he saith: Mr. Stetson has twice visited me and questioned me in reference to the Reis apparatus. I believe the first time was in 1884 and the last in the spring of this year, 1886. I gave Mr. Stetson the same explanation as I have given to-day, so far as I can recall. He never showed me drawings or copies of telephone apparatus.

x-Int. 6. Did he not say to you that he represented the United States of America in an effort to prove that Reis, and not Bell, was the first inventor of the speak-

ing telephone, and state fully what he said on the subject?

SIXTH. To the sixth cross-interrogatory he saith:

Soweit ich mich entsinne, hat Herr Stetson mir nur gesagt, dass durch die Regierung der Vereinigten Staaten gegen Bell processirt werde. In wessen Auftrag er (Stetson) gekommen sei, mich zu befragen, hat mir derselbe nicht gesagt. Ich entnahm seiner Unterhaltung, dass er gekommen sei, zu erforschen, ob Ph. Reis, und nicht Bell, der erste Erfinder des Sprach-Telephon gewesen sei.

SIXTH. To the sixth cross-interrogatory he saith: So far as I can remember, Mr. Stetson only said to me that a suit had been begun against Bell by the Government of the United States. He, Stetson, did not tell me in whose behalf he had come to question me. I gathered from his conversation that he had come to investigate whether Philipp Reis, and not Bell, was the first inventor of the speaking telephone.

x-Int. 7. If you shall say in your direct examination that you had special knowledge of the Reis telephone, explain how it happened that you knew more about it than Reis, Boettger and other scientific men who published their knowledge on the subject?

SEVENTH. To the seventh cross-interrogatory he saith:

Besondere, detaillirte Kenntnisse des Reis'schen Telephons habe ich nie gehabt. Ich habe nie einen solchen Apparat in seinen Einzelheiten so genau kennen gelernt, um z. B., einen solchen herstellen zu können. Die Kenntnisse eines Telephons, wie sie Ph. Reis, Böttger und andere Männer der Wissenschaft besessen haben, oder besitzen, habe ich nie mir angeeignet.

SEVENTH. To the seventh cross-interrogatory he saith: I never had an especial and minute knowledge of the Reis telephone. I have never come to know such an apparatus so well that I could, for example, construct it. I have never acquired the knowledge of a tele-

phone to such a degree as Philipp Reis, Boettger and other scientific men possessed or possess.

x-Int. 8. Do you know of any publications made before 1876 which gave to the world the information you now think you then had, and if so, name them and produce copies ?

EIGHTH. To the eighth cross-interrogatory he saith :

Im Jahrgange 1863 der Gartenlaube ist ein Aufsatz über Telephone erschienen. Andere Publikationen über Telephone sind mir nicht bekannt, um sie bezeichnen zu können.

EIGHTH. To the eighth cross-interrogatory he saith : In the volume of the " Gartenlaube " for 1863, there is an article about telephones. I have no knowledge of other publications about telephones that I can refer to.

x-Int. 9. If you should say that you held conversations through the Reis telephone before 1876, say who assisted you, when it was, and describe the apparatus you used, and where the speaking instrument was placed in respect to yourself or the other listeners who heard it with you. Was it on the table, and were you standing near it? Was it in a public assembly, and was it heard by the persons present generally? Where was the transmitter, and who talked to it on the occasion when you heard the conversation or reading? Were the exhibitions published in newspapers or journals ; and if so, name the journals and annex copies ?

NINTH. To the ninth cross-interrogatory he saith :

Ich habe mit dem Erfinder Ph. Reis, meinem Schwager, dessen Apparate benutzt und zwar in den Jahren 1859 bis 1864, in seiner Wohnung in Friedrichsdorf, sowie bei Gelegenheit eines Vortrages von Ph. Reis in den Physikalischen Verein zu Frankfort, a. M. und einem auf der Naturforscher-Versammlung zu Giessen, beide im Jahre, 1863. Da ich bei Ph. Reis, dem Erfinder wohnte, so zog mich derselbe bei den meisten seiner Versuchen mit Telephonen zu Hülfe. Meistens gab ich den Sprecher ab, aber um mir zu zeigen, wie

der Apparat functionire, liess mich Reis auch bisweilen den Hörer sein. Der eine Apparat befand sich im Wohnhause von Ph. Reis, u. der Andere in der Scheune, jenseits des Hofes des Wohnhauses. Die zuletzt benutzten Apparate waren gleich denen, wovon Sie mir heute Zeichnungen oder Abbildungen mit 1 A und 1 B bezeichnet, vorlegten. Die Apparate wurden auf einen Tisch gestellt und sprach oder sang ich, davor sitzend, hinein. Der Sprech-Apparat stand ebenfalls auf einem Tische und die Hörer sassen davor, ihr Ohr dem Apparat nähernd, um zu hören, was vom Sende-Apparat aus gesprochen oder gesungen wurde. In Frankfurt a. M. und Giessen, war ich bei den Vorträgen nur Sprecher, und habe ich den Saal der Zuhörer nicht betreten. Ich erinnere mich nicht genau der Lokalitäten in den genannten Orten, glaube aber, dass ich im ersteren Orte in einem von dem Hörersaale durch einen Garten getrennten Lokale mit dem Sende-Apparate mich befand. Ich entsinne mich, in dem Jahrgange, 1863, der Gartenlaube einen Aufsatz über Reis' sche Telephone gelesen zu haben.

NINTH. To the ninth cross-interrogatory he saith : I used the apparatus only with its inventor Philipp Reis, and in his dwelling in Friedrichsdorf in the years 1859 to 1864, and also on the occasion of a lecture by Philipp Reis before the Physikal Verein in Frankfort-on-the-Main, and at a lecture before the Assembly of Natural Scientists in Giessen, both in the year 1863. As I lived with Philipp Reis, the inventor, he took me with him to assist him in the most of his experiments with telephones. I generally did the talking, but in order to show me how the apparatus worked Reis allowed me sometimes to listen. One instrument was placed in the dwelling house of Philipp Reis, and the other in the shed on the other side of the yard of the dwelling house. The instruments used were like those, the drawings of which have been shown me to-day, marked 1A and 1B. The instruments were placed upon a table, and I sitting

in front of the table spoke or sang into them. The receiver stood likewise upon a table and the hearers sat in front of it bringing their ears near to the instrument in order to hear what was spoken or sung into the transmitter. At Frankfort and Giessen, I was at both lectures only speaker and I did not enter the lecture room. I do not exactly remember the situation in the above-mentioned places, but I think that I was with the transmitter in a place separated from the lecture-room by a garden. I only remember to have read in the volume of the " Gartenlaube " for 1863 an article about Reis' telephone.

x-Int. 10. When did you become connected by marriage with Reis ?

TENTH. To the tenth cross-interrogatory he saith :

Ph. Reis heirathete meine Schwester im Jahre 1858.

TENTH. To the tenth cross-interrogatory he saith : Philipp Reis married my sister in the year 1858.

x-Int. 11. Explain the manner in which the tests were applied in order to know whether listeners actually heard what was said, or whether they only imagined they heard something.

ELEVENTH : To the eleventh cross-interrogatory he saith :

Ich bin öfters Hörer gewesen, doch kann ich keine Methode für die Lauschenden angeben. Der Lauschende näherte sein Ohr dem Sprech-Apparat. Von einer Einbildung oder Täuschung der Lauschenden, konnte nicht die Rede sein ; was durch den Reis'schen Apparat gesprochen oder gesungen wurde, wurde gehört und verstanden von den Lauschenden, darüber kann kein Zweifel obwalten.

ELEVENTH. To the eleventh cross-interrogatory he saith : I have often been a listener, yet I cannot indicate any method for the listeners. The listener brought his ear close to the receiver. There was no chance for any imagination or self-deception on the part of the listener. What was spoken or sung through the Reis

instrument was heard and understood by the listeners ; of that there can be no doubt.

x-Int. 12. If you should say that Reis used water in his transmitter will you explain how he prevented it from wetting the stretched membrane and destroying its elasticity.

TWELFTH. To the twelfth cross-interrogatory he saith :

Darauf vermag ich nicht zu antworten, u. kann darüber keine Auskunft geben.

TWELFTH. To the twelfth cross-interrogatory he saith : This question I cannot answer, and cannot give any information about.

x-Int. 13. Did you ever see any published account by Reis, or any other experimenter, of the use of water at the contact points of the telephone for any purpose ; and if so, in what publication did you see, and annex a copy of it.

THIRTEENTH. To the thirteenth cross-interrogatory he saith.

Dergleichen sah ich nie.

THIRTEENTH. To the thirteenth cross-interrogatory he saith : I never saw anything of the sort.

x-Int. 14. Isn't it certain that if water were applied at the contact point it would be scattered at once by the vibration of the membrane and wet it, and also be decomposed by the current of electricity passing through it at that point ?

FOURTEENTH. To the fourteenth cross-interrogatory he saith :

Diese Frage vermag ich nicht zu beantworten.

FOURTEENTH. To the fourteenth cross-interrogatory he saith : This question I am not able to answer.

x-Int. 15. Who first spoke to you on the subject of water used by Reis to operate his telephone ?

FIFTEENTH. To the fifteenth cross-interrogatory he saith :

Diese Frage vermag ich ebensowenig zu beantworten.

FIFTEENTH. To the fifteenth cross-interrogatory he saith: This question also I cannot answer.

x-Int. 16. Have you ever seen or read, or heard read these interrogatories, or has any one stated to you the substance of them, or any of them, before they were propounded to you one at a time by the examining officer, and answered by you?

SIXTEENTH. To the sixteenth cross-interrogatory he saith:

Diese Frage beantworte ich mit Nein.

SIXTEENTH. To the sixteenth cross-interrogatory he saith: This question I answer with "no."

(Signed)

JOHANN PHILIPP SCHMIDT.

Examination taken, reduced to writing and by the witness subscribed and sworn to this fourteenth day of December, A. D. one thousand eight hundred and eighty-six, before

LEOP. STRUBE,
Commissioner.

Deposition of Conrad Bohn, a witness produced, sworn and examined the 23d day of December, in the year one thousand eight hundred and eighty-six, at Frankfort, in the Empire of Germany, under and by virtue of a commission issued out of the Circuit Court of the United States for the District of New Jersey, in a certain cause therein depending and at issue, wherein the American Bell Telephone Company and others are plaintiffs and the New Jersey Telephone Company and others are defendants:

Conrad Bohn, of Aschaffenburg, Germany, professor of physics, aged 55 years and upwards, being duly and publicly sworn, pursuant to the directions hereto annexed, and examined on the part of the defendants, doth depose and say as follows:

Int. 1. Please state what is your name, age, residence and occupation ?

Für seine Antwort auf die erste Frage sagt Zeuge wie folgt aus:

Dr. Konrad Bohn, ich bin 55 Jahre alt, bin Professor der Physikan der Kgl. Forstschule in Aschaffenburg, und bin in Aschaffenburg ansässig.

To the first interrogatory he saith: Dr. Conrad Bohn; I am 55 years old, and professor of physics at the Royal School Forestry in Aschaffenburg, and live in Aschaffenburg.

Int. 2. Were you acquainted with the late Philipp Reis, of Frankfort, Germany ?

Für seine Antwort auf die zweite Frage sagt Zeuge wie folgt aus:

Ich war mit dem verstorbenen Philipp Reis von Frankfurt bekannt.

To the second interrogatory he saith: I was acquainted with the late Philipp Reis, of Frankfort.

Int. 3. If to the last interrogation you answer, yes, state, if you know, what was the occupation of the said Reis during the years 1859 to 1874 inclusive, or during any portion of that period in which you had knowledge of the matters now inquired about?

Für seine Antwort auf die dritte Frage sagt Zeuge wie folgt aus:

Ich kannte Hrn. Reis seit 1868. Er war damals Lehrer an einer Knaben-Erziehungsanstalt in Friedrichsdorf.

To the third interrogatory he saith: I knew Mr. Reis from the year 1863. He was at that time teacher in a boys' educational institution in Friedrichsdorf.

Int. 4. Do you know whether the said Reis was engaged during that period or at any portion of that period, in experiments having in view the transmission of articulate speech or other sounds by means of electricity? If you answer yes, and that he was so engaged

in respect to either or both the subjects named, please state how you know the fact?

Für seine Anwort auf die vierte Frage sagt Zeuge wie folgt aus:

Hr. Reis experimentirte zu jener Zeit in beiden Richtungen.

Ich weiss solches aus eigener Erfahrung; indem ich Ende 1863, oder Anfang 1864 mit Hrn. Reis selbst und Anderen, derartige Versuche in Giessen anstellte.

To the fourth interrogatory he saith: Mr. Reis experimented at that time in both directions. I know this of my own knowledge, inasmuch as I at the end of 1863 or the beginning of 1864 made such experiments at Giessen in connection with Mr. Reis himself and others.

Int. 5. Were you during the period above named ever present when the said Reis or any other person in his presence experimented with any apparatus in transmitting, or attempting to transmit, speech or other sounds; if you shall answer yes, please state on how many occasions, if more than one, at what time or times and place or places, as nearly as you can remember. Please answer this question as to any occasion when, in the absence of said Reis, such experiments were made by other persons by means of any instruments referred to in the seventh interrogatory?

Für seine Antwort auf die fünfte Frage sagt Zeuge wie folgt aus:

Wie in Frage 4 besagt:

Ja.

Solche Versuche fanden mindestens zweimal derart statt, dass ich sichere Erinnerung daran habe; ich wohnte aber noch mehreren solchen bei, die mir nichts Neues mehr brachten, und desshalb nicht so fest in meiner Erinnerung stehen; dies war entweder Ende 1863 oder Anfang 1864 die ersten Male, dann im Frühling 1864, und zuletzt im September 1864; die ersten Versuche, wei die letzten, fanden im Hause des Hrn. Prof. Buff in

Giessen im, von der Universität gemietheten Hörsaal der Physick statt; einer der unvollkommen in der Erinnerung stehenden Versuche, fand im Universitäts-Gebäude zu Giessen statt. (Sitzungslokal des Ober-Hessischen Vereins für Naturkunde.)

Prof. Reis liess seinen Apparat für Prof. Buff und mich einige Tage in Giessen, und wir machten auch in Abwesenheit von Reis Versuche.

To the fifth interrogatory he saith: As in my fourth answer I have said; yes.

Such experiments took place at least twice in such a way that I have a clear recollection of them. I was also present at other such experiments which added nothing to my knowledge, and therefore are not so clearly impressed upon my memory. These first occasions were either in the latter part of 1863 or beginning of 1864, then in the spring of 1864, and finally in September, 1864. The first experiments, as well as the last, took place in the house of Prof. Buff in Giessen, in the physical lecture room hired from the university. One of the experiments, which I only imperfectly remember, took place in the university building of Giessen (Assembly room of the Upper Saxon Society for Nat. History). Prof. Reis left his apparatus in Giessen several days with Prof. Buff and myself, and we made experiments also in the absence of Reis.

Int. 6. If, in answer to the last interrogatory, you shall have named any occasion or occasions such as are in that interrogatory referred to, please state the names of all persons present on such occasion as nearly as you can remember, and the character and results of the experiments then carried on, and especially the results thereof, so far as they related to the transmission of articulate speech or other vocal sounds, or to the transmission of sounds other than vocal sounds, and particularly whether any articulate words, spoken or sung, were sent and received; and the words or sentences, so far as you can remember them; and whether

such words or sentences as you may give were all which were so sent and received?

Für Antwort auf die sechste Frage, sagt Zeuge wie folgt aus :

Bei den gut in Erinnerung stehenden Versuchen, waren gegenwärtig, und waren als Hörer oder Sprecher benutzt, Prof. Buff, dessen Tochter (ungefähr dreizehn Jahre alt) ein Knabe Thering (dreizehn bis vierzehn Jahre alt), Prof. Lange, ich selbst und theilweise Hr. Reis. Bei den anderen Versuchen waren Mitglieder des Ober-Hessischen Vereins und Mitglieder und Theilnehmer der Naturforscher-Versammlung, in grosser Zahl ;—Die Versuche erstreckten sich sowohl auf die Mittheilung gesungener, als auch lediglich gesprochener Worte, und zwar wurden beide zuweilen gut verstanden.

Ja, sie wurden gesendet und empfangen ; es wurde deutlich verstanden, das gesungene Lied " Schlesswig Holstein, Meerumschlungen,"—ferner, erinnere ich mich, dass die obengenannten Kinder klagten, es sei *kalt*, u. dass man ihr Lachen deutlich auf die Entfernung wahrnahm. Es wurden andere Mittheilungen noch verstanden und errathen, hinzüglich welcher, meine Erinnerung für eine *eidliche* Ausage, nicht sicher genug ist ; ich füge hinzu, dass selbst wenn die einzelnen Worte nicht deutlich genug verstanden wurden, doch der Charackter der Mittheilung, ob Frage, ob Antwort, u. s. w., zweifellos erkannt wurde.

To the sixth interrogatory he saith : In the best remembered experiments there were present and employed as listeners or speakers Prof. Buff, his daughter (about thirteen years old), a boy named Thering (thirteen or fourteen years old), Prof. Lange, myself, and at times Mr. Reis. In the other experiments there were present in great numbers members of the Upper Saxon Society and members and guests of the Assembly of Natural Scientists. The experiments extended as well to the transmission of sung as of single spoken words, and in fact both were well understood. Yes,

they were sent and received. The song "Schleswig, Holstein Meerumschlungen" was plainly understood. Further, I remember that the children mentioned above complained that it was cold, and that their laughing in the distance was clearly heard. Other messages were also understood and guessed, in regard to which my remembrance is not clear enough for testimony under oath; I would add, moreover, that even when the single words were not clearly enough understood, the character of the message, whether a question, answer, etc., was understood without any difficulty.

Int. 7. Look at the pictorial representations hereunto annexed and marked , and state whether you recognize in any of them representations of instruments used in any experiments to which you may have testified for the transmission of speech or other sounds by electricity; and if you answer yes, state which of the drawings you so recognize, and say whether, according to your recollection, such drawings accurately show such instruments; or, if any of them differ in any way, wherein they differ. If you say that none of the instruments shown in these pictorial representations were used, please describe as nearly as you can the instruments actually used in the experiments concerning which you may have testified?

Für seine Antwort auf die siebente Frage, sagt Zeuge wie folgt aus:

Ja.

Ich kenne Zeichnung 1a und 1b, ebenfalls 4a und 4b an, als darstellend die von mir gekannten und hinsichtlich ihrer Wirkung geprüften Telephone. Der in den genannten Abbildungen vorhanden "*Klopfer*" oder "Anrufe-Apparat," fehlte bei dem ersten, mir vorgekommenen Telephon; bei dem zweiten Apparate, war dieser Zusatz angebracht.

To the seventh interrogatory he saith: Yes, I recognize the drawings 1A and 1B, as well as 4A and 4B, as representing the instruments known to me and

called from their method of operation telephone. The sounder or signaling apparatus represented in the above-mentioned drawings was wanting in the first telephone which came to my notice, but in the second apparatus this addition was made.

Int. 8. If you shall have answered that you were ever present at experiments such as are referred to in the 5th, 6th and 7th interrogatories, and that articulate speech or any vocal sounds were transmitted, state whether entire sentences were transmitted and received or only single words, and state also, if you can, what sentences or words then spoken or sung were heard by you at the receiver, and what, if any, were reported by others then listening at the receiver. Explain, for the information of the Court, the respective position of the transmitting and receiving instruments, your position with reference to each, and your position with reference to any person who reported any words or sentences spoken or sung as having been received?

Für seine Antwort auf die achte Frage, sagt Zeuge wie folgt aus:

Es wurde versucht ganze gesprochene Sätze zu übermitteln, auch Lieder grösserer Länge, und verschiedene Strophen derselben; es wurde, selbst bei den best gelungenen Versuchen, bei denen ich als Hörer thätig war, nicht jedes einzelne Wort deutlich verstanden, doch konnte aus den verstandenen Worten in manchen Fällen der Satz durch Errathen ergänzt werden. Ich hörte die Worte des Liedes "Schlesswig Holstein"— das Wort "kalt" in dem Sätzchen "Es ist kalt hier!" andere sind mir für *eidliche* Versicherung nicht deutlich genug in der Erinnerung.

Die Mittheilung konnte gleichzeitig von anderen vernommen werden. Da ich nicht besondere Fertigkeit besitze, mangelhafte Mittheilungen durch das Ohr leicht zu verstehen, so kam es vor, dass Prof. Buff eine Mittheilung verstand, die mir undeutlich blieb, obgleich ich das Ohr am Brette des Empfangs-Apparats hatte,

also in günstigerer Stellung mich befand als Prof. Buff.

Der Empfangs-Apparat (1 *a*) war in einem Zimmer des oberen Stockwerks (drei Treppen), der Hör-Apparat (1 *b*) stand auf dem grossen Tische, im Hör-Saale zu ebener Erde des Hauses von Prof. Buff. Ich war sowohl als Sprecher, als auch als Hörer thätig. Ebenso die anderen bei diesen Versuchen betheiligten Personen, abwechselnd. Da ich mich als schlechter Sprecher erwies, verblieb ich meistens im Hör-Saale bei bem Hör-Apparat (1 *b*).

To the eighth interrogatory he saith: We tried to transmit whole spoken sentences, also songs of considerable length and different stanzas. In the most successful experiments in which I took part as listener, we could not understand distinctly every single word, still from the words which were understood in most cases the sense of the sentence could be made out. I heard the words of the song "Schleswig-Holstein," the word "kalt" in the short sentence "Es is kalt hier." Others I do not remember distinctly enough for testimony under oath. The transmission could be understood at the same time by others. As I do not possess an especial aptitude for easily catching imperfect transmission, it would happen that Prof. Buff understood a sentence which was not plain to me, although I had my ear on the sounding board of the receiver, and was thus in a more favorable position than Prof. Buff. The transmitter 1A was in a room of the upper story (three stories); the receiver 1B stood on the large table in the lecture room, on the ground floor of Prof. Buff's house. I took part not only as speaker, but as listener, and other persons also at these experiments were alternately so occupied. As I proved to be a poor speaker, I remained most of the time in the lecture room near the receiver 1B.

Int. 9. State also if you saw the said Reis use any water or other fluid in or about his apparatus, or any

part thereof, and particularly how the same was used and for what purpose, if you know?

Für seine Antwort auf die neunte Frage sagt Zeuge wie folgt aus:

Ja. Es wurden Säueren für die Batterie benützt, welche der Diener in Stand setzte.

To the ninth interrogatory he saith: Yes, acids were used for the battery, which the servant put in order.

Int. 10. Do you know or can you set forth any other matter or things which may be a benefit or advantage to the parties at issue in this cause, or either of them, or that may be material to the subject of this your examination, or the matters in question in this cause. If yea, set forth the same fully and at large in your answer?

Für seine Antwort auf die zehnte Frage sagte Zeuge wie folgt aus:

Nein.

To the tenth interrogatory he saith: No.

The complainants object to the direct interrogatories as follows:

To the Fourth Int. Objected to as incompetent and irrelevant; because it is of no importance in law what Philip Reis may have done in Germany or other foreign country, unless Mr. Bell's invention or discovery had been patented or described in some printed publication.

To the Fifth Int. Same objection.

To the Sixth Int. Same objection.

To the Seventh Int. Same objection.

To the Eighth Int. Same objection; and further, because the last paragraph is leading, and calculated to instruct the witness to describe an operation which neither Reis nor any other person who ever saw his

telephone ever described in any publication, or suggested, even when Reis himself gave the most ample explanations of his apparatus and its operation.

DICKERSON & DICKERSON,
Complainants' Solicitors,
By J. J. S.

CROSS-INTERROGATORIES.

KREUZFRAGEN:

x-Int. 1. Are you the same person who wrote a letter dated September 10, 1882, published in a book entitled "Philip Reis, Inventor of the Telephone. By Sylvanus P. Thompson," which, as printed in that book in English, is as follows:

"MOST ESTEEMED SIR:

"I willingly answer, as well as I am able to do so, the questions put by you. In order to explain that my recollections may not have all the sharpness that might be wished, I make the following prefatory statement: I have, about 1863, held numerous conferences with Mr. Reis and with my deceased colleague, Professor H. Buff, of Giessen, and on these occasions have argued the question how it is that the transmission of thoughts to a distance by the sensation of the ear has a distinctly less value than transmission by that which is written.

* * *

"And now to your questions. I was not at Stettin in 1863. At the experiments at Giessen in the Naturforscher Assembly, on 21st September, 1864, I was present; the short notice about them in the journal ('Tagesblatt') is from my pen. I was Secretary of the Assembly and of the Physical Section. I remember, however, almost absolutely nothing about *these* experi-

ments. But I remember well that *previously*—therefore probably as early as 1863—having jointly made the experiments with Reis' telephone in Buff's house at Giessen * * * I have *myself*, as speaker and as hearer, at least twice, in the presence of Reis, made the experiments.

" It was known to me (in 1863-64) that Reis intended to transmit words, and certainly spoken words as well as those sung. My interest in the matter was, however, a purely scientific one, not directed to the application as a means of profit.

" With great attention the sense of the words was understood. I have understood such myself, without knowing previously what would be the nature of the communication through the telephone. Words sung, especially well accentuated and peculiarly intoned, were somewhat better (or rather less incompletely) understood than those spoken in the ordinary manner. There was indeed a boy (son of Privy-Councillor Ihering, now of Göttingen, then of Giessen), who was known as specially accomplished as a speaker. He had a rather harsh North-German dialect, and after the first experiments hit on the right way to speak best, essential for understanding. I myself *did not* understand Professor Buff through the telephone. Whether the speaker could be recognized by his voice I doubt. We knew beforehand each time who speaks. Yet I remember that a girl could be distinguished from that boy by the voice.

" The ear was at times laid upon the box of the apparatus, also upon the table which supported the telephone. Then it was attempted to hear at a distance, with the ear in the air; in this respect, when singing, with good result. At times the lid was taken off, or the same was connected more or less tightly or loosely with the lower part. The result of these changes I can no longer give with distinctness. * * *

" Should you desire further information, I am ready to give you it according to my best knowledge.

" Hochachtungsvoll ergebenster,

" Dr. C. Bohn.

" Aschaffenburg,

" 10th September, 1882."

Für seine Antwort auf die erste Kreuzfrage sagt Zeuge wie folgt aus:

Ja.

To the first cross-interrogatory he saith: Yes.

x-Int. 2. In that letter you say in reference to the experiments tried at Geissen September 21, 1864, that you remember " almost absolutely nothing about these experiments. Whether a speaker could be recognized by his voice I doubt." Is that your present recollection?

Für seine Antwort auf die zweite Kreuzfrage sagt Zeuge wie folgt aus:

Die Naturforscher-Versammlung zu Giessen begann erst am 18ten September, 1864, es ist in der Frage also wohl gemeint, der Vortrag, den Herr Reis etwa am 21ten September, nicht am 12ten, hielt. Ich habe an diesen Vortrag gegenwärtig keine Erinnerung, was sich daraus erklären mag, dass er mir nichts Neues bot, indem ich die Sache von früher gründlicher kannte, als durch diesen Vortrag zu erlangen war; dass ich ferner zu jener Zeit mit Geschäften überladen und übermüdet war. Meine Erfahrungen über das Erkennen der Stimme, datiren nicht vom September 1864, sondern von der früheren Zeit, für welche sichere Erinnerung vorhanden ist. Ich bin noch der Meinung dass wegen der Nebengeräusche und sonstiger Umstände halber keine Wahrscheinlichkeit bestand, jemanden an der Stimme zu erkennen; weiss aber ferner dass ich und andere an der Stimme erkannten ob der Knabe oder das Mädchen sprach, von welchen wir wussten dass sie allein zur Zeit am Sprech-Apparat sei.

To the second cross-interrogatory he saith: The Assembly of Natural Scientists at Giessen only began on the 18th of September, 1864. The question, therefore, probably refers to the lecture which Mr. Reis delivered about the 21st of September. I have at present no remembrance of this lecture, which can be explained by the fact that it presented nothing new to me, since I had previously a more thorough knowledge of the matter than could be acquired from this lecture. Moreover, I was at that time overburdened and tired out with business. My experience in reference to recognizing voices dates not from September, 1864, but from the earlier time of which I have a distinct recollection. I am still of the opinion that on account of the accompanying sounds (Nebengeräusche) and other circumstances there was no probability of recognizing any one by his voice; but I further know that myself and others recognized by the voice whether the boy or the girl was talking, from which we knew that she alone at the time was at the transmitter.

x-Int. 3. Do you not remember that Professor H. Buff, of Geissen, read a paper at the same meeting on the tones of iron and steel rods, when magnetized, and referred to the Reis receiver as an illustration of that phenomenon?

Für seine Antwort auf die dritte Kreuz-frage sagt Zeuge wie folgt aus:

Ja. Ich erinnere mich dieses Vortrags von Prof. Buff, aber nicht das, und ob er das Reis-Telephon damit in Verbindung brachte.

To the third cross-interrogatory he saith: Yes; I remember this lecture of Professor Buff, but not that, and whether he introduced the Reis telephone in connection therewith.

x-Int. 4. Was not Professor Buff a friend of Reis, and a person in whose house Reis had tried his experiments in your presence in 1863?

Für seine Antwort auf die vierte Kreuze-frage sagt Zeuge wie folgt aus :

Ja. In Buff's Hause fanden die Versuche statt zum Theil in jenem Raum, welchen er von der Universität vermiethet hatte. Eine nähere Freundschaft zwischen den Hrn. Reis und Buff bestand meines Wissens nicht. Hr. Reis kam zu Prof. Buff, wie auch zu mir, als zu Fachleuten.

To the fourth cross-interrogatory he saith : Yes ; the experiments took place in Buff's house, partly in that room which he had hired of the University. A closer friendship between Mr. Reis and Mr. Buff did not exist, so far as my knowledge extends. Mr. Reis came to Professor Buff, as well as to me, as specialists.

x-Int 5. Do you think that Professor Buff was as well acquainted with the operation of the Reis telephone as you were at that time ?

Für seine Antwort auf die fünfte Kreuze-frage sagt Zeuge wie lolgt aus :

Ja.

To the fifth cross-interrogatory he saith : Yes.

x-Int. 6. Was not Professor Helmholtz at that meeting, and Professor Bottger ?

Für seine Antwort auf die sechste Kreuze-frage sagt Zeuge wie folgt aus :

Die Frage geht auf die Sitzung der Naturforcher-Versammlung in September, 1864. Ich habe bereits erklärt, an den Vortrag von Reis bei dieser Gelegenheit, keine Erinnerung zu haben, also auch nicht an jene Personen, die seinem Vortrage beiwohnten.

To the sixth cross-interrogatory he saith : This question refers to the meeting of the Assembly of Natural Scientists in September, 1864. I have already explained that I have no remembrance of the lecture of Reis on this occasion, neither of those persons who were present at the lecture.

x-Int. 7. Look at the book now shown you, containtaining a lecture by Reis on his telephone, and say if

you do not recognize the handwriting of Professor Böttger on the 64th page of it ?

Für seine Antwort auf die siebte Kreuz-frage sagt Zeuge wie folgt aus :

Frage 7 ist gegenstandslos, da das Buch fehlt, ausserdem ist mir Prof. Boettger's Handschrift wenig bekannt.

To the seventh cross-interrogatory he saith : Question seven is unintelligible, as the book is wanting, and, moreover, I am little acquainted with Professor Bottger's handwriting.

x-Int. 8. You say in that letter that you did not understand Professor Buff through the telephone. Is that your present recollection ?

Für seine Antwort auf die achte Kreuz-frage sagt Zeuge wie folgt aus :

Ja.

To the eighth cross-interrogatory he saith : Yes.

x-Int. 9. What was the cause of your writing that letter ?

Für seine Antwort auf die neunte Kreuz-frage sagt Zeuge wie folgt aus :

Ich schrieb den Brief, auf Einladung von Prof. Sylvanus P. Thompson, der mich bat ihm mitzutheilen, was ich von dem Reis Telephon wisse, da er die Geschichte desselben schreiben wolle.

To the ninth : I wrote the letter upon the invitation of Professor Sylvanus P. Thompson, who asked me to to communicate to him what I knew of the Reis telephone, as he wished to write a history of it.

x-Int. 10. Did not Sylvanus P. Thompson, of England, and Albert Stetson, of America, come to see you on the subject ?

Für seine Antwort auf die zehnte Kreuz-frage, sagt Zeuge wie folgt aus :

Nein, ich habe Prof. Thompson nie gesehen, auch Hrn. Albert Stetson sah ich nie persönlich.

To the tenth cross-interrogatory he saith : No ; I

have never seen Professor Thompson, nor Mr. Stetson, personally.

x-Int. 11. Did they not talk over the subject with you and tell you that they were engaged in establishing the reputation of Reis as the inventor of the telephone?

Für seine Antwort auf die elfte Kreuz-frage, sagt Zeuge wie folgt aus:

Nein.

To the eleventh cross-interrogatory he saith: No.

x-Int. 12. Did not Stetson visit you in the year 1886 on the same subject?

Für seine Antwort auf die zwölfte Kreuz-frage, sagt Zeuge wie folgt aus:

Nein. Ich wechselte aber Briefe in 1886 mit Hrn. Stetson.

To the twelfth cross-interrogatory he saith: No; but I exchanged letters in 1886 with Mr. Stetson.

x-Int. 13. Did he not tell you that he was the agent of the Government of the United States, for the purpose of establishing the fact that Reis, and not Bell, was the inventor of the telephone?

Für seine Antwort auf die dreizehnte Kreuz-frage sagt Zeuge wie folgt aus:

Hr. Stetson sprach überhaupt nicht mit mir, sondern schrieb mir wie folgt: "I am, as I think I informed you, sent here by the Solicitor-General of the United States to inquire respecting the work of Phillipp Reis upon the telephone. * * * This case is not in the interest of any company, brings no pecuniary advantage to the Government, but is undertaken in order to settle definitely the question as to who is entitled to the honor of having invented the telephone," etc., etc.

To the thirteenth cross-interrogatory he saith: Mr. Stetson never spoke with me at all, but wrote me as follows: "I am, as I think I informed you, sent here by the Solicitor-General of the United States to inquire respecting the work of Philip Reis upon the telephone.

* * * This case is not in the interest of any company, brings no pecuniary advantage to the Government, but is undertaken in order to settle definitely the question as to who is entitled to the honor of having invented the telephone," etc.

x-Int. 14. Had you not read in a newspaper, or heard that Mr. Stetson was in Germany for that purpose?

Für seine Antwort auf die vierzehnte Kreuzfrage sagt Zeuge wie folgt aus:

Nein.

To the fourteenth cross-interrogatory he saith: No.

x-Int. 15. State fully what representations Mr. Stetson made to you on that subject?

Für seine Antwort auf die fünfzehnte Kreuzfrage sagt Zeuge wie folgt aus:

Habe ich ausführlich in der 13ten Kreuzfrage beantwortet.

To the fifteenth cross-interrogatory he saith: I have thoroughly answered this question in the answer to thirteenth cross-question.

x-Int. 16. In your letter you say that "it was attempted to hear at a distance with the ear in the air in this respect, when singing, with good results." State more fully what you now think you remember of songs heard in that way. What were the words you heard, if any?

Für seine Antwort auf die sechszehnte Kreuzfrage, sagt Zeuge wie folgt aus:

Das Lied "Schlesswig-Holstein."

Für den letzten Theil der Frage reicht meine Erinnerung nicht aus.

To the sixteenth cross-interrogatory he saith: The song "Schlesswig Holstein." My recollection is not sufficiently distinct to enable me to answer the last part of the question.

x-Int. 17. Explain what you mean by saying that "at times the lid was taken off, or the same was con-

nected more or less tightly or loosely with the lower part"?

Für seine Antwort auf die siebzehnte Kreuzfrage sagt Zeuge wie folgt aus:

Der in Zeichnung 1 b. mit C. bezeichnete Theil, (Deckel) wurde zuweilen in der Stellung der Figur, zuweilen niedergeklappt auf das Resonanz-brett, dann auch noch fest angedrückt, verwendet.

To the seventeenth cross-interrogatory he saith: The part marked C (cover) in the drawing 1B was sometimes used in the position shown in the figure, at other times shut down upon the sounding board, and also pressed down tightly upon it.

x-Int. 18. Was this done for the purpose of trying to make the sounds more distinct?

Für seine Antwort auf die achtzehnte Kreuzfrage sagt Zeuge wie folgt aus:

Ja. Es geschah in der Absicht die Umstände zu prüfen, welche Einfluss auf die Deutlichkeit der Telephonischen Mittheilung haben könnten.

To the eighteenth cross-interrogatory he saith: It was done for the purpose of testing the circumstances which might have influence upon the clearness of the telephonic transmission.

x-Int. 19. Who made the experiments—was it Reis or some other person?

Für seine Antwort auf die neunzehnte Kreuzfrage sagt Zeuge wie folgt aus:

Die Versuche wurden zum Theil in Gegenwart, zum Theil in Abwesenheit von Hrn. Reis angestellt, und waren verschiedene Personen, bald Sprecher, bald Hörer; bei den fraglichen Versuchen, konnte Hr. Reis, wegen Heiserkeit, nicht als Sprecher thätig sein.

To the nineteenth cross-interrogatory he saith: The experiments were made partly in the presence partly in the absence of Mr. Reis, and there were different persons present at the aforesaid experiments, some-

times as speakers, sometimes as hearers. Mr. Reis, on account of hoarseness, could not act as speaker.

x-Int. 20. If you should say that Reis used water in his transmitter, will you explain how he prevented it from wetting the stretched membrane and destroying its elasticity?

Für seine Antwort auf die zwanzigste Kreuz-frage, sagt Zeuge wie folgt aus:

Die Frage fällt weg, da ich nicht sagte, dass Reis am Gebe-Apparat Wasser benutzte.

To the twentieth cross-interrogatory he saith: There is no reason for this question, as I did not say that Reis used water in the transmitter.

x-Int. 21. Did you ever see any published account by Reis, or any other experimenter, of the use of water at the contact points of his telephone for any purpose; and, if so, what publication did you see it in, and annex a copy of it?

Für seine Antwort auf die einundzwanizgste Kreuz-frage, sagt Zeuge wie folgt aus:

Nein.

To the twenty-first cross-interrogatory he saith: No.

x-Int. 22. Isn't it certain that if water were applied at the contact point it would be scattered at once by the vibration of the membrane, and wet it; and also be decomposed by the current of electricity passing through it at that point?

Für seine Antwort auf die zweiundzwanzigste Kreuz-frage, sagt Zeuge wie folgt aus:

Da in meiner Gegenwart kein Wasser am Gebe-Apparat benutzt wurde, so kann ich auf Frage 22 nicht antworten. Meine Meinung, was geschehen wäre, wenn Wasser an die Contacktstelle gebracht worden, ist keine Zeugenaussage, könnte höchstens Gegenstand eines wissenschaftlichen Gutachtens sein.

To the twenty-second cross-interrogatory he saith: As no water was used in the apparatus in my presence I cannot answer question twenty-two. My opinion as

to what would happen if water was placed between the contact points is no proper testimony; at the most, it would be a matter of scientific opinion.

x-Int. 23. Who first spoke to you on the subject of water used by Reis to operate his telephone?

Für sein Antwort auf die dreiundzwanzigste Kreuzfrage, sagt Zeuge wie folgt aus:

Niemand.

To the twenty-third cross-interrogatory he saith: No one.

x-Int. 24. Have you ever seen or read, or heard read, or has any person stated to you the substance of these questions, or of any part of them, before they were propounded to you one by one and answered by you before the examining officer?

Für seine Antwort auf die vierundzwanzigste Kreuzfrage, sagt Zeuge wie folgt aus:

Nein.

To the twenty-fourth cross-interrogatory he saith: No.

Deposition of HEINRICH HOLD, a witness produced, sworn and examined the sixteenth day of December, in the year one thousand eight hundred and eighty-six, at Friedrichsdorf, in the empire of Germany, under and by virtue of a commission issued out of the Circuit Court of the United States for the District of New Jersey, in a certain cause therein depending and at issue, wherein the American Bell Telephone Company and others are plaintiffs, and the New Jersey Telephone Company and others are defendants.

HEINRICH HOLD, of Friedrichsdorf, Germany, tanner, aged 55 years and upwards, being duly and publicly sworn, pursuant to the directions hereto annexed, and examined on the part of the defendants, doth depose and say as follows:

Int. 1. Please state what is your name, age, residence and occupation?

Für seine Antwort auf die erste Frage sagt Zeuge wie folgt aus:

Heinrich Hold, fünfundfünzig Jahre alt, Gerber, Friedrichsdorf.

To the first interrogatory he saith: Heinrich Hold; 55 years old; tanner; Friedrichsdorf.

Int. 2. Were you acquainted with the late Philipp Reis, of Frankfort, Germany?

Für seine Antwort auf die zweite Frage sagt Zeuge wie folgt aus:

Ja.

To the second interrogatory he saith: Yes.

Int. 3. If to the last interrogation you answer yes, state, if you know, what was the occupation of the said Reis during the years 1859 to 1874, inclusive, or during any portion of that period in which you had knowledge of the matters now inquired about?

Für seine Antwort auf die dritte Frage sagt Zeuge wie folgt aus:

Philipp Reis war an dem hiesigen Institute, während der ganzen Zeit von 1859 bis 1874, Lehrer der Naturwissenschaften und Mathematik, und beschäftigte sich nebenbei stets mit physikalischen und chemischen Untersuchungen.

To the third interrogatory he saith: During the whole time from 1859 to 1874, Philipp Reis was teacher of the natural sciences and mathematics at the Institute in this place, and was besides constantly occupied with physical and chemical investigations.

Int. 4. Do you know whether the said Reis was engaged during that period, or at any portion of that period, in experiments having in view the transmission of articulate speech or other sounds by means of electricity? If you answer yes, and that he was so engaged in respect to either or both the subjects named, please state how you know the fact?

Für seine Antwort auf die vierte Frage sagt Zeuge wie folgt aus:

Jawohl. Die Versuche wurden hier in Friedrichsdorf gemacht; die Distance zwischen der Aufgabe und der durch Electricität erzeugten Wiedergabe von Worten und Gesänge mehr oder weniger verständlich, beträgt ungefähr vierzig Meter. Ich habe den Haupt Versuchen beigewohnt. Es wurde in das aus Gyps construirte mit Membran und Platinblech versehene sogenannte Trummelfell, welches gegen ein Metall Hämmerchen vibrirte, und so die Induction herstellte, gesprochen, gesungen, gegeigt und Clavier gespielt, und auf eben angegebener Entfernung die respective Töne und Laute mehr oder weniger deutlich reproducirt.

To the fourth interrogatory he saith: Yes; indeed. The experiments were made here in Friedrichsdorf. The distance was about forty metres between the transmitting station and the place where there took place a reproduction by means of electricity, of words and songs, more or less understood. I took part in the chief experiments. We spoke, sung, played on the violin and piano, and reproduced more or less distinctly the respective tones and sounds at the above-mentioned distance into the so-called drum-head, made of plaster of paris and provided with a membrane and a strip of platinum, against which there vibrated a small metal hammer, thus producing the induction.

Int. 5. Were you, during the period above named, ever present when the said Reis or any other person in his presence experimented with any apparatus in transmitting or attempting to transmit speech or other sounds? If you shall answer yes, please state on how many occasions; if more than one; at what time or times; and place or places, as nearly as you can remember. Please answer this question as to any occasion when in the absence of said Reis such experiments were made by other persons by means of any instruments referred to in the 7th interrogatory?

Für seine Antwort auf die fünfte Frage sagt Zeuge wie folgt aus:

Ja. Es ist wiederholt geschehen, und haben solche Versuche in meiner und Anderer Gegenwart mehrmals stattgefunden; solches fand statt in ersten Jahren der Erfindung in seiner eigenen Wohnung in Friedrichsdorf. Solche Versuche fanded nur in Gegenwart und unter Mitwirkung von Herrn Reis statt.

To the fifth interrogatory he saith: Yes; it has repeatedly happened, and such experiments have several times taken place in my presence and in that of others. Such experiments took place in his own house in Friedrichsdorf, in the years in which the instrument was invented. Such experiments only took place in the presence of and with the assistance of Mr. Reis.

Int. 6. If, in answer to the last interrogatory, you shall have named any occasion or occasions such as are in that interrogatory referred to, please state the names of all persons present on each occasion, as nearly as you can remember, and the character and results of the experiments then carried on, and especially the results thereof, so far as they related to the transmission of articulate speech or other vocal sounds, or to the transmission of sounds other than vocal sounds, and particularly whether any articulate words, spoken or sung, were sent and received, and the words or sentences, so far as you can remember them, and whether such words or sentences as you may give were all which were so sent and received?

Für seine Antwort auf die sechste Frage sagt Zeuge wie folgt aus:

Wie gesagt, fanden solche Versuche nur in Gegenwart und unter Mitwirkung von Herrn Reis statt. Bei solchen Versuchen, waren ausser den bereits verstorbenen Personen zugegen: Philipp Schmidt in Wilhelmshafen, Anton Horkheimer aus Frankfurt am Main, in Manchester, England; es wurden Versuche gemacht mit Clavierspiel, Geige, Gesang und Sätzesprechen, welches Alles in den meisten Fällen vernehmbar reproducirt wurde: gesprochene und gesungene Worte zum

Beispiel "Ich hatte einen Kameraden" und andere mehr wurden auf Entfernungen gesandt und empfangen.

To the sixth interrogatory he saith: As I have said, such experiments took place only in the presence of and with the assistance of Mr. Reis. At such experiments there were present, besides the persons already mentioned, Philipp Schmidt of Wilhelmshafen, and Anton Horkheimer, of Frankfort-on-the-Main, now at Manchester, England. Experiments were made with playing the piano, violin, singing and speaking sentences, all of which in most cases was reproduced and understood. Words spoken and sung, for example, "Ich hatte einen Kameraden," and many others were transmitted and received at a distance.

Int. 7. Look at the pictorial representations hereunto annexed and marked , and state whether you recognize in any of them representations of instruments used in any experiments to which you may have testified, for the transmission of speech or other sounds by electricity; and if you answer yes, state which of the drawings you so recognize, and say whether, according to your recollection, such drawings accurately show such instruments; or, if any of them differ in any way, wherein they differ. If you say that none of the instruments shown in these pictorial representations were used, please describe as nearly as you can the instruments actually used in the experiments concerning which you may have testified?

Für seine Antwort auf die siebente Frage sagt Zeuge wie folgt aus:

Ich habe die angehefteten und wie folgt 1 A, 1 B, 2 A, 3 A, 3 B, 3 C, 4 A, 4 B, 5 A, 5 B, markirten bildlichen Darstellungen angesehen und als solche von Herrn Reis konstruirte Apparate behufs Telephonie wiedererkannt.

Verwahre mich dagegen detaillirt angeben zu können

ob Zeichnungen und bezüglich konstruirte Apparate des Herrn Reis genau übereinstimmen.

To the seventh interrogatory he saith: I have looked at the annexed drawings marked 1A, 1B, 2A, 3A, 3B, 3C, 4A, 4B, 5A, 5B, and recognize them as apparatus constructed by Mr. Reis for the purposes of telephony. I would guard against, however, pretending to be able to give details, and say whether the drawings and the apparatus constructed according to them exactly agree with that of Mr. Reis.

Int. 8. If you shall have answered that you were ever present at experiments such as are referred to in the 5th, 6th and 7th interrogatories, and that articulate speech or any vocal sounds were transmitted, state whether entire sentences were transmitted and received, or only single words, and state also, if you can, what sentences or words then spoken or sung were heard by you at the receiver, and what, if any, were reported by others then listening at the receiver.

Explain for the information of the Court the respective position of the transmitting and receiving instruments, your position with reference to each and your position with reference to any person who reported any words or sentences spoken or sung as having been received.

Für seine Antwort auf die achte Frage sagt Zeuge wie folgt aus:

Bei solchen primitiven Versuchen wurden ganze Sätze, einzelne Worte, Gesang u. s. w. mehr oder weniger deutlich vernommen. Ganz deutlich vernahm ich: "Ich hatte einen Kamaraden," "Philipp Schmidt."

Nur der dem Sprecher (accepteur) zunächste konnte es deutlich vernehmen. Der Empfänger resp. Tonerzeugnungs-Apparat (Ohr) befand sich in der Wohnstube des Herrn Reis. Der Verbindungsdraht ging von da durch den Hof in die Scheuer woselbst der Sprecher (accepteur) aufgestellt war. Habe wiederholt mich an der Aufgabe und Empfangstation beschäftigt. Die

dabei anwesenden Personen waren Lehrer, Collegen des Instituts Garnier.

To the eighth interrogatory he saith: In such primitive experiments, whole sentences, single words, songs, etc., were more or less clearly understood. I understood very clearly "Ich Hatte Kameraden," "Philipp Schmidt." Only the one who got nearest to the receiver (accepteur) could understand it plainly. The transmitter or tone producing apparatus (ear) was in the sitting room. The connecting wire passed from there through the court to the shed where the transmitter (accepteur) was set up. Have repeatedly been occupied both at the transmitting and receiving stations. The persons present on these occasions were teachers, colleagues of the Garnier Institute.

Int. 9. State also if you saw the said Reis use any water or other fluid in or about his apparatus, or any part thereof, and particularly how the same was used, and for what purpose, if you know?

Für seine Antwort auf die neunte Frage sagt Zeuge wie folgt aus:

Wenn ich zugegen war, waren alle Vorbereitungen so weit getroffen, dass wir sofort telephonirten. Wasser oder andere Flüssigkeiten wurden während der verhältnissmässig kurzen Zeit nicht herbeigeschafft.

To the ninth interrogatory he saith: When I was present all the preparations had been so far made that we went right to telephoning. Water or other liquids were not brought during the relatively short time.

Int. 10. Do you know, or can you set forth, any other matter or things which may be a benefit or advantage to the parties at issue in this cause, or either of them, or that may be material to the subject of this your examination, or the matters in question in this cause. If yea, set forth the same fully and at large in your answer?

Für seine Antwort auf die zehnte Frage sagt Zeuge wie folgt aus:

Ich weiss nichts.

To the tenth interrogatory he saith: I know nothing.

CROSS-INTERROGATORIES.

KREUZFRAGEN.

x-Int. 1. In what year were you born?

Fur sein Antwort auf die erste Kreuzfrage sagt Zeuge wie folgt aus:

Den 9ten November, 1831.

To the first cross-interrogatory, he saith: The ninth of November, 1831.

x-Int. 2. What is your present occupation, and how long have you been so occupied?

Für seine Antwort auf die zweite Kreuzfrage sagt Zeuge wie folgt aus:

Ich betreibe eine Waschleder-Gerberei seit 1865.

To the second cross-interrogatory, he saith: I have been carrying on a wash leather tannery since 1865.

x-Int. 3. Are you the same person who wrote a letter to S. P. Thompson, published in his book entitled "Philip Reis, Inventor of the Telephone," as follows:

"ESTEEMED SIR:

"I have much pleasure in furnishing you with the following particulars concerning my late colleague, Philipp Reis, the inventor of the telephone. He was himself educated at the Garnier's Institute in Friedrichsdorf, where I was also teacher of mathematics. I knew him very well during his lifetime. Among his numerous original researches, his invention of the telephone was the principal one. His idea was to reproduce the tones both of musical instruments and of the human voice by means of electricity, using a

covered wire wound in a spiral round an iron core, the same being placed upon a resonant box. In this he succeeded, inasmuch as with an apparatus, which he showed to the Physikalischer Verein in Frankfurt-a-M., in the year 1861, he reproduced music, singing, single words and short sentences; all of which were distinctly audible over a short distance from his dwelling-house through the yard to the barn. Every voice was not equally well adapted for speaking into the apparatus, neither could every ear understand the telephone language equally well. Words spoken slowly and singing both in a middle tone, were the most easy to reproduce. I helped Mr. Reis to make many of his experiments and have spoken and sung into the telephone, the same being generally heard and understood. I have also heard and understood short sentences when I was standing at the end station. A brother-ln-law of Mr. Reis, who is now paymaster in the Imperial Navy at Wilhelmshaven, generally conducted the speaking and singing in the telephone.

"HEINRICH HOLD."

Für seine Antwort auf die dritte Kreuzfrage sagt Zeuge wie folgt aus:

Ja.

To the third cross-interrogatory, he saith: Yes.

x-Int. 4. What induced you to write that letter?

Für seine Antwort auf die vierte Kreuzfrage sagt Zeuge wie folgt aus:

Das Interesse, dass der Wahrheit die Ehre gebührt und meinem Freund Reis die Ehre als Erfinder des Telephons unangefochten erhalten bliebe.

To the fourth cross-interrogatory, he saith: The interest of doing honor to truth and that the honor of my friend Reis, as inventor of the telephone should remain unimpeached.

x-Int. 5. Did Professor Thompson inform you that he was employed by persons who were sued as infringers

of a patent for the telephone, and that he was making up a book in aid of their defense ?

Für seine Antwort auf die fünfte Kreuzfrage sagt Zeuge wie folgt aus :

Professor Thompson hat sich an mich ohne ander-, weitige Mittheilung nur um Erkundigung über Reis Telephon gewandt.

To the fifth cross-interrogatory, he saith : Prof. Thompson applied to me, telling me nothing further than that he wished for information in reference to the Reis telephone.

x-Int. 6. Did you ever see a Mr. Stetson from the United States on the same subject ?

Für seine Antwort auf die sechste Kreuzfrage sagt Zeuge wie folgt aus :

Ja.

To the sixth cross-interrogatory, he saith : Yes.

x-Int. 7. Did he inform you that he was acting for persons charged as infringers of patents for the telephone ?

Für seine Antwort auf die siebente Kreuzfrage sagt Zeuge wie folgt aus :

Nein. Stetson erwies sich stets pro Reis contra Bell.

To the seventh cross-interrogatory, he saith : No ; Stetson showed himself always for Reis contra Bell.

x-Int. 8. Did he not inform you that he was employed by the Government of the United States for the purpose of proving that Reis, and not Bell, was the inventor of the telephone ? State fully what he did inform you on the subject of his object and employment.

Fúr seine Antwort auf die achte Kreuzfrage sagt Zeuge wie folgt aus :

Nein.

To the eighth cross-interrogatory, he saith : No.

x-Int. 9. In your letter you say that Reis, " with an apparatus which he showed at the Physikaleschen Verin

at Frankfurt-a-M., in the year 1861, reproduced music, singing, single words and short sentences, all of which were distinctly audible over a short distance from his dwelling-house through the yard to the barn." Does this statement refer to that which is published in *Jahresbricht der Physikalischen Vereins zu Frankfurt-a-M.*, 1860–61, pp. 57–64, by Reis himself ?

Für seine Antwort auf die neunte Kreuzfrage sagt Zeuge wie folgt aus :

Ja.

To the ninth cross-interrogatory, he saith : Yes.

x-Int. 10. Did you know more about this telephone, its mode of operation, and its capacity, than Reis did who wrote that lecture ?

Für seine Antwort auf die zehnte Kreuzfrage sagt Zeuge wie folgt aus :

Nein.

To the tenth cross-interrogatory, he saith : No.

x-Int. 11. You say in your letter: " I helped Mr. Reis to make many of his experiments, and have spoken and sung into the telephone, the same being generally heard and understood." Did you mean by that to say that a person standing " at the end station " generally understood what was said at the other end ?

Für seine Antwort auf die elfte Kreuzfrage sagt Zeuge wie folgt aus :

Ja.

To the eleventh interrogatory, he saith : Yes.

x-Int. 12. Did this occur before the lecture or afterwards ?

Für seine Antwort auf die zwölfte Kreuzfrage sagt Zeuge wie folgt aus :

Vor dem Vortrage.

To the twelfth cross-interrogatory, he saith : Before the lecture.

x-Int. 13. Did it occur before Reis published his advertising circular for the sale of his telephones by Albert & Son in 1863, or afterwards ?

Für seine Antwort auf die dreizehnte Kreuzfrage sagt Zeuge wie folgt aus:

Ja, es ereignete sich vorher.

To the thirteenth cross-interrogatory, he saith: Yes, it happened before.

x-Int. 14. Did it occur before or after 1873, when Albert again published his descriptive catalogue of the telephone of Reis, and referred his readers to Pisko for a description of the Reis instrument?

Für seine Antwort auf die vierzehnte Kreuzfrage sagt Zeuge wie folgt aus:

Es ereignete sich vor 1873.

To the fourteenth cross-interrogatory, he saith: It happened before 1873.

x-Int. 15. If you think you knew more than Reis did of the operation and capacity of his telephone, do you think you knew more than Albert did, who manufactured and sold them for Reis, and who described them and their operation directly and by reference to Pisko's description?

Für seine Antwort auf die fünfzehnte Kreuzfrage sagt Zeuge wie folgt aus:

Bin überzeugt dass ich über Reis' Telephon weniger wusste als Albert, geschweige denn als Reis selbst, der Erfinder.

To the fifteenth cross-interrogatory, he saith: I am convinced that I knew less about the Reis telephone than Albert, much less than Reis himself, the inventor.

x-Int. 16. If you should say that Reis used water in his transmitter, will you explain how he prevented it from wetting the stretched membrane and destroying its elasticity?

Für seine Antwort auf die sechszehnte Kreuzfrage sagt Zeuge wie folgt aus:

Resultirt aus der Antwort auf die neunte direkte Frage, dass ich nichts davon weiss.

To the sixteenth cross-interrogatory, he saith: It re-

sults from the answer to the ninth direct-question, that I know nothing about it.

x-Int. 17. Did you ever see any published account of Reis or any other experimenter, of the use of water at the contact points of his telephone for any purpose, and, if so, in what publication did you see it and annex a copy of it?

Für seine Antwort auf die siebenzehnte Kreuzfrage sagt Zeuge wie folgt aus:

Nein.

To the seventeenth cross-interrogatory, he saith: No.

x-Int. 18. Isn't it certain that if water were applied at the contact point it would be scattered at once by the vibration of the membrane and wet it; and also be decomposed by the current of electricity passing through it at that point?

Für seine Antwort auf die achtzehnte Kreuzfrage sagt Zeuge wie folgt aus:

Ich weiss es nicht.

To the eighteenth cross-interrogatory, he saith: I do not know.

x-Int. 19. Who first spoke to you on the subject of water used by Reis to operate his telephone?

Für seine Antwort auf die neuzehnte Kreuzfrage sagt Zeuge wie folgt aus:

Niemand.

To the nineteenth cross-interrogatory, he saith: Nobody.

x-Int. 20. Have you seen, read or heard read these questions, or been told their import, until you heard them read to you one by one by the officer who propounds them?

Für seine Antwort auf die zwanzigste Kreuzfrage sagt Zeuge wie folgt aus:

Nein! Habe sie zuerst von dem Beamten, der mir sie stellte, vorgelesen gehört. Durch Herrn A. Stetson war ich früher insoweit davon benachrichtigt, dass man

mich demnächst in Sache des Reis'schen Telephone amtlich verhören würde.

To the twentieth cross-interrogatory, he saith: No, I have first heard them read to me by the official who put them to me. I was before informed by Mr. A. Stetson that in a short time my testimony would be taken officially in reference to the Reis telephone.

ALVESTO S. HOGUE,
Commissioner.

RETURN.

I, ALVESTO S. HOGUE, the Commissioner within named, do hereby certify and return to the Circuit Court of the United States of America for the District of New Jersey, that I have duly executed the within commission in manner and form as is therein and thereby commanded, and that the execution thereof will fully appear by the schedule to the said commission and the accompanying interrogatories annexed. I further certify that no one was present while the depositions were being taken excepting myself, the within-named Commissioner, and Clement Garnier, a clerk employed by me to write the answers; and that the execution thereof will fully appear by the schedule to the said commission and the accompanying interrogatories annexed.

Given under my hand and seal this 22d day of December, A. D. 1886.

ALVESTO S. HOGUE,
Commissioner.

Deposition of J. HAUSSER, a witness, produced, sworn and examined, the 20th day of December, in the year one thousand eight hundred and eighty-six, at Wasselheim, in the Empire of Germany, under and by virtue

of a commission issued out of the Circuit Court of the United States for the District of New Yersey, in a certain cause therein depending and at issue, wherein the American Bell Telephone Company and others are plaintiffs, and the New Jersey Telephone Company and others are defendants :

J. HAUSSER, of Wasselheim, Germany, not in business, aged 65 years and upwards, being duly and publicly sworn, pursuant to the directions hereto annexed, and examined on the part of the defendants, doth depose and say as follows :

Int. 1. Please state what is your name, age, residence and occupation ?

Für seine Antwort auf die erste Frage sagt Zeuge wie folgt aus :

Johann Hausser, 65 Jahre alt, eben keinen Beruf, bis 1885 Musiklehrer in Wasselheim gewesen, wohnhaft zu Wasselheim.

To the first interrogatory he saith : Johann Hauser ; 65 years old ; at present in no business ; was until 1885, music teacher in Wasselheim ; living now in Wasselheim.

Int. 2. Were you acquainted with the late Philipp Reis, of Frankfort, Germany ?

Für seine Antwort auf die zweite Frage, sagt Zeuge wie folgt aus :

Ich war mit Ph. Reis sehr befreundet ; wir redeten uns sogar per " Du " an.

To the second interrogatory he saith : I was a very intimate friend of Philipp Reis, in fact, we addressed each other with " Du."

Int. 3. If to the last interrogation you answer yes ; state if you know what was the occupation of the said Reis during the years 1859 to 1874, inclusive, or during any portion of that period in which you had knowledge of the matters now inquired about ?

Für seine Antwort auf die dritte Frage sagt Zeuge wie folgt aus :

Während der Jahren 1859 bis inclusive 1874 war Reis Lehrer an dem Garnier'schen Institut in Friedrichsdorf. Reis starb, so viel ich mich erinnern kann, im Monat Januar, 1874. Anfänglich war Reis Lehrer der Unterklassen für das Französische; später lehrte derselbe in den oberen Klassen Mathematik, Chemie und Physik. Nebenbei war Reis immer damit beschäftigt, wie er sich ausdrükte, den Ton auf telegraphischem Wege zu übertragen. Wo er ging und stand waren dies seine Träume.

To the third interrogatory he saith: During the years 1859 to 1874, inclusive, Reis was teacher at the Garnier Institute in Friedrichsdorf. Reis died, if I remember rightly, in the month of January, 1874. In the beginning Reis was teacher of French for the lower classes, later he taught the upper classes mathematics, chemistry and physics. In connection with his teaching Reis was always busy trying, as he expressed it, to transmit tones (den Ton) telegraphically. Wherever he was this was his dream.

Int. 4. Do you know whether the said Reis was engaged during that period, or at any portion of that period, in experiments having in view the transmission of articulate speech or other sounds by means of electricity. If you answer yes, and that he was so engaged in respect to either or both the subjects named, please state how you know the fact?

Für seine Antwort auf die vierte Frage sagt Zeuge wie folgt aus:

Nein. Bei dem ersten Versuche, zu welchem mich Reis zuzog, hatte derselbe einen Draht von seinem Laboratium auf den Speicher gespannt; dort wurde ich aufgestellt um zu hören, ob ein Laut vernehmbar sei. Reis laborirte unten, ich oben mit meiner eigenen Geige, auf der er das eine Ende des Drahtes befestigt hatte. Ich konnte deutlich einen schnarrenden Ton vernehmen. Ob Reis sich bei diesem Versuch der Elektrizität bedient hatte weiss ich nicht.

To the fourth interrogatory he saith: No. In the first experiment to which Reis took me he had a wire stretched from his laboratory to the shed, and I was placed there in order to listen and hear whether a sound could be understood. Reis was at work below and I was upstairs with my violin, upon which he had fastened the one end of his wire. I could recognize clearly a rattling tone. I do not know whether in this experiment Reis made use of electricity.

Int. 5. Were you during the period above named ever present when the said Reis or any other person in his presence experimented with any apparatus in transmitting or attempting to transmit speech or other sounds. If you shall answer yes, please state on how many occasions, if more than one; at what time or times, and place or places. as nearly as you can remember. Please answer this question as to any occasion when in the absence of said Reis such experiments were made by other persons by means of any instruments referred to in the 7th interrogatory?

Für seine Antwort auf die fünfte Frage sagt Zeuge wie folgt aus:

Ja. Solche Versuche fanden sehr oft statt in meiner Gegenwart. Unter mehreren anderen Versuchen will ich nur den erwähnen, bei welchen Hr. Professor Opel aus Frankfurt anwesend war; bei diesem Versuche wurde ich ersucht einzelne Töne, dann 2 Töne zugleich, dann drei Klänge auf dem Klavier zu spielen. Wurde nacher abberufen an den Ort, wo Ph. Reis und Opel die Töne in Empfang nahmen, und wurde aufgefordert die Reihenfolge meines Spielens auf dem Klavier zu sagen. Zum grossen Vergnügen des Hrn. Opel hatte derselbe genau die Töne notirt, die ich gespielt hatte. Ausgenommen war der Ton c., ich hatte das gestrichene c. unter der ersten Linie angeschlagen, während Hr. Opel das c. im dritten Zwischenraum notirt hatte. Bei diesem Versuche sind auch Worte übertragen worden, ja sogar Sätze und ganze Abhandlungen. Wir konnten die

Worte ziemlich deutlich verstehen, dies war jedoch nur dadurch möglich dass der Zuhörer ein zweites Exemplar desjenigen Buches in der Hand hatte, aus welchem gelesen wurde. Worte die auf s. oder r. endigten, waren undeutlicher zu verstehen. Bei dem ersten Versuch stand das Klavier im ersten Stockwerke, eine Treppe hoch, während die Zuhörer, Hr. Professor Opel und Reis in einem ca. 30 m. entfernten kleinen Zimmerchen in der Scheune hinten dem Garten sich befanden. Der Draht ging vom Klavier aus durch Hof, Scheune, bis in das betreffende Zimmer. Bei den Vorlesungen befand ich mich mit Ph. Reis und Opel in diesem Zimmer, der Sprecher befand sich in dem Reis'schen Hause, in welchem Zimmer kann ich jedoch nicht angeben. Vorerwähnte Versuche fanden in Friedrichsdorf statt.

Bei den Versuchen war Reis stets zugegen, ohne ihn fanden in meiner Gegenwart keine Versuche statt.

To the fifth interrogatory he saith: Yes. Such experiments very often took place in my presence. Among our other experiments I will only mention the one at which Prof. Opel of Frankfort was present. At this experiment I was requested to play upon the piano single tones, then two tones at the same time, then trichords.

Afterwards I was called to the place where they were by Messrs. Reis and Opel, who were listening to the tones, and was requested to notice carefully the order of my playing upon the piano. To the very great delight of Mr. Opel, he had written down the tones exactly as I played them. There was an exception in the case of the tone C. I had struck the C of the first added line below, while Mr. Opel had written down the C in the third space of the scale. In these experiments there were also transmitted words, long sentences and whole paragraphs. We could understand the words quite plainly; this was, however, only possible by the listener having in his hand a second copy of the book out of which one was reading. Words

ending in *s* or *r* were less clearly understood. In the first experiment the piano was in the first story, while the listeners, Prof. Opel and Reis were in a little room in a shed about thirty metres distant, at the end of the garden. The wire extended from the piano through the court to the shed and into the above-mentioned room, While the reading was going on I was with Messrs. Reis and Opel in this room. The speaker was in Reis' house, but in what room I cannot say. The above-mentioned experiment took place in Friedrichsdorf. Reis was always present at the experiments, and no experiments took place in my presence without him.

Int. 6. If in answer to the last interrogatory you shall have named any occasion or occasions such as are in that interrogatory referred to, please state the names of all persons present on each occasion, as nearly as you can remember, and the character and results of the experiments then carried on, and especially the results thereof, so far as they related to the transmission of articulate speech or other vocal sounds, or to the transmission of sounds other than vocal sounds, and particularly whether any articulate words, spoken or sung, were sent and received, and the words or sentences, so far as you can remember them, and whether such words or sentences as you may give were all which were so sent and received ?

Für seine Antwort auf die sechste Frage sagt Zeuge wie folgt aus :

Professor Opel aus Frankfurt, Lehrer Keep ; Lehrer Monch, z. Zt. in Frankfurt; Lehrer Bachmann, aus Friedrichsdorf; Professor Garnier, aus Frankfurt; Lehrer Dr. Schenk, aus Friedrichsdorf; die Transmission von artikulirten Worten war nicht verständlich genug, damit der Apparat in Gebrauch gesetzt werden konnte Die Transmission von Stimmtönen und Musiktönen war sehr deutlich; artikulirte, gesprochene und gesungene Worte wurden auf eine Entfernung von un-

gefähr 30 Meter gesandt und empfangen; einzelne Worte oder Sätze, die gesprochen wurden, weiss ich nicht mehr.

To the sixth interrogatory he saith: Prof. Opel, of Frankfort; the teachers Keeb, Monch, at that time in Frankfort, Bachmann, of Friedrichsdorf, Prof. Garnier, of Frankfort, and Dr. Schenk, of Friedrichsdorf. The transmission of articulate words was not plain enough so that the apparatus could be brought into use. The transmission of vocal tones and music tones was very plain; articulated, spoken, and sung words were transmitted and received at a distance of about thirty metres. I do not recall the single words or sentences that were spoken.

Int. 7. Look at the pictorial representations hereunto annexed and marked, and state whether you recognize in any of them representations of instruments used in any experiments to which you may have testified for the transmission of speech or other sounds by electricity; and if you answer yes, state which of the drawings you so recognize, and say whether, according to your recollection, such drawings accurately show such instruments; or, if any of them differ in any way, wherein they differ. If you say that none of the instruments shown in these pictorial representations were used, please describe as nearly as you can the instruments actually used in the experiments concerning which you may have testified?

Für seine Antwort auf die siebente Frage sagt Zeuge wie folgt aus:

Ich habe die erwähnten bildlichen Darstellungen angesehen, und erkenne das Bild 2 A, 5 A, 5 B als von Reis gebrauchtes, so weit ich mich erinnern kann an.

To the seventh interrogatory he saith: I have looked at the illustrations mentioned, and recognize the instruments 2A, 5A and 5B, as those used by Reis, as nearly as I can remember.

Int. 8. If you shall have answered that you were ever

present at experiments such as are referred to in the 5th, 6th and 7th interrogatories, and that articulate speech or any vocal sounds were transmitted, state whether entire sentences were transmitted and received, or only single words, and state also, if you can what sentences or words then spoken or sung were heard by you at the receiver, and what, if any, were reported by others then listening at the receiver. Explain for the information of the Court the respective position of the transmitting and receiving instruments, your position with reference to each, and your position with reference to any person who reported any words or sentences spoken or sung as having been received?

Für seine Antwort auf die achte Frage sagt Zeuge wie folgt aus:

Ich erinnere mich noch sehr gut, dass ganze Worte und Sätze gesprochen wurden, ich dieselben auch gehört habe, mich jedoch derer nicht mehr erinnere. Ich weiss nicht, ob andere mir umstehende Personen, als ich, am Sprecher gelauscht habe, mir gesagt haben, dass sie auch etwas verstanden.

Das eine Instrument, an dem der Sprecher stand, hatte ein von Reis sogenanntes "Ohr" in der Hand, sprach hinein; der Lauschende hielt dasselbe Instrument an sein Ohr. Ich habe nur an dem Instrument gelauscht; der Sprecher stand ca. 30 meter enfernt; ich habe blos zugehört, nicht selbst hinein gesprochen.

To the eighth interrogatory he saith: I remember very well that whole words and sentences were spoken and I have also heard the same, though I cannot now remember them. I do not remember whether other persons standing around while I listened to the talking have told me that they also heard something. The speaker stood at one instrument, had in his hand the instrument called "ear" by Reis, and spoke into it; the listener held the instrument to his ear. I have only been a listener at the instrument; the speaker was

distant from me about thirty metres. I have only listened and never spoken into the instrument.

Int. 9. State also if you saw the said Reis use any water or other fluid in or about his apparatus, or any part thereof, and particularly how the same was used, and for what purpose, if you know?

Für seine Antwort auf die neunte Frage sagt Zeuge wie folgt aus :

Ich habe nie den Reis irgend welche Flüssigkeit an seinen Apparat zur Anwendung bringen sehn.

To the ninth interrogatory he saith: I never saw Reis put any liquid whatever in his apparatus.

Int. 10. Do you know or can you set forth any other matter or things which may be a benefit or advantage to the parties at issue in this cause, or either of them, or that may be material to the subject of this your examination or the matters in question in this cause. If yea, set forth the same fully and at large in your answer?

Für seine Antwort auf die zehnte Frage sagt Zeuge wie folgt aus :

Nein.

To the tenth interrogatory he saith : No.

CROSS-INTERROGATORIES.

KREUZFRAGEN.

x-Int. 1. In what year were you born?

Für seine Antwort auf die erste Kreuz-frage sagt Zeuge wie folgt aus :

Ich wurde im Jahre 1821 geboren.

To the first cross-interrogatory he saith: I was born in the year 1821.

x-Int. 2. What is your present occupation, and how long have you been engaged in it?

Für seine Antwort auf die zweite Kreuz-frage sagt Zeuge wie folgt aus :

Eine gegenwärtige Beschäftigung habe ich nicht.

To the second cross-interrogatory he saith : I have at present no employment.

x-Int. 3. What was your occupation, and where did you reside from 1860 to 1864 ?

Für seine Antwort auf die dritte Kreuz-frage, sagt Zeuge wie folgt aus,

Meine Beschäftigung war Lehrer. Von 1860-1864 wohnte ich in Friedrichsdorf.

To the the third cross-interrogatory he saith : My employment was teaching. From 1860 to 1864 I lived in Friedrichsdorf.

x-Int. 4. When were you first asked to testify about the Reis machine, and by whom ?

Für seine Antwort auf die vierte Kreuz-frage, sagt Zeuge wie folgt aus :

Ich bin noch nie um gerichtliche Aussage ersucht worden.

To the fourth cross-interrogatory he saith : I have never been asked for legal testimony.

x-Int. 5. Did not Mr. Stetson, of the United States, talk with you on the subject during the past year ?

Für seine Antwort auf die fünfte Kreuz-frage, sagt Zeuge wie folgt aus :

Nein.

To the fifth cross-interrogatory he saith : No.

x-Int. 6. Did he not say to you that he represented the United States of America in an effort to prove that Reis, and not Bell, was the first inventor of the speaking telephone ; and state fully what he said on the subject ?

Für seine Antwort auf die sechste Kreuz-frage, sagt Zeuge wie folgt aus :

Nein.

To the sixth interrogatory he saith : No.

x-Int. 7. If you shall say in your direct examination

that you had special knowledge of the Reis telephone, explain how it happened that you knew more about it than Reis, Böttger and other scientific men who published their knowledge of the subject?

Für seine Antwort auf die siebente Kreuz-frage, sagt Zeuge wie folgt aus;

Ich glaube nicht mehr Kenntniss, wie Reis und Böttger, von dem Telephon zu haben.

To the seventh cross-interrogatory he saith: I do not pretend to have more knowledge of the telephone than Reis and Boettger.

x-Int 8. Do you know of any publications made before 1876 which gave to the world the information you now think you then had; and if so, name them and produce copies?

Für seine Antwort auf die achte Kreuz-frage, sagt Zeuge wie folgt aus:

Ich habe keine Druckschriften, welche vor dem Jahre 1876 erschienen sind, und die Information über das Telephon enthalten.

To the eighth cross-interrogatory he saith: I have seen no publications which appeared before the year 1876, containing information in reference to the telephone.

x-Int. 9. If you should say that you held up conversations through the Reis telephone before 1876, say who assisted you, when it was, and describe the apparatus you used, and where the speaking instrument was placed in respect to yourself or the other listeners who heard it with you. Was it on the table, and were you standing near it? Was it in a public assembly, and was it heard by the persons present generally? Where was the transmitter, and who talked to it on the occasion when you heard the conversation, or reading? Were the exhibitions published in newspapers or journals; and if so, name the journals and annex copies?

Für seine Antwort auf die neunte Kreuz-frage, sagt Zeuge wie folgt aus:

Es war niemand behüflich, wie Ph. Reis und sein Schwager; es war dies Anfangs der sechziger Jahre; ich benutzte das sogenannte "Ohr," an welchem ich lauschte, welches die nachstehende Form hatte,

und an der engern Seite mit einer Schweineblase übezogen war. Man hatte das Sprech-instrument in der Hand gehabt. Die Nebenstehenden mussten der Reihenfolge nach, das Instrument an's Ohr halten. Gewöhnlich hat man das "Ohr" auf den Tisch gestellt, und sich daneben gesetzt und an's Ohr gehalten. Es war in der Wohnung des Ph. Reis in Friedrichsdorf. Das Instrument stand vorne in Wohmhaus, und ein Schwager von Ph. Reis sprach auf dasselbe zu; diese Versuche wurden nicht veröffentlicht.

To the ninth cross-interrogatory he saith: There was no one helping in the experiment, except Mr. Reis and his brother-in-law. It was at the beginning of the sixties. I used the so-called ear at which to listen; this had the following form, and was covered at the narrow end with a pig's bladder. The receiver was held in the hand, and those standing around must take their turn at holding the instrument to the ear. Generally the "ear" was placed upon the table, and we sat around and held it against our ear. It was in the house of Mr. Reis, at Friedrichsdorf. The instrument stood in the dwelling-house, and a brother-in-law of Mr. Reis spoke into it. These experiments were not published.

x-Int. 10. If you should say that Reis used water in his transmitter, will you explain how he prevented it from wetting the stretched membrane and destroying its elasticity?

Für seine Antwort auf die zehnte Kreuz-frage, sagt Zeuge aus wie folgt:

Reiss benutzte kein Wasser, um die Membran anzufeuchten.

To the tenth cross-interrogatory he saith : Reis used no water to moisten the membrane.

x-Int. 11. Did you ever see any published account by Reis, or any other experimenter, of the use of water at the contact points of the telephone for any purpose ? and if so, in what publication did you see it, and annex a copy of it ?

Für seine Antwort auf die elfte Kreuz-frage, sagt Zeuge wie folgt aus :

Nein.

To the eleventh cross-interrogatory he saith : No.

x-Int. 12. Isn't it certain that if water were applied at the contact point it would be scattered at once by the vibration of the membrane, and wet it ; and also be decomposed by the current of electricity passing through it at that point ?

Für seine Antwort auf die zwölfte Kreuz-frage, sagt Zeuge wie folgt aus :

Ich weiss nicht.

To the twelfth cross-interrogatory he saith : I don't know.

x-Int. 13. Who first spoke to you on the subject of water used by Reis to operate his telephone ?

Für seine Antwort auf die dreizehnte Kreuz-frage, sagt Zeuge wie folgt aus :

Niemand.

To the thirteenth cross-interrogatory he saith : No one.

x-Int. 14. Have you ever seen, or read, or heard read, these interrogatories, or has any one stated to you the substance of them, or any of them, before they were propounded to you one at a time by the examining officer, and answered by you ?

Für seine Antwort auf die vierzehnte Kreuz-frage, sagt Zeuge wie folgt aus :

Nein.

To the fourteenth cross-interrogatory he saith : No.

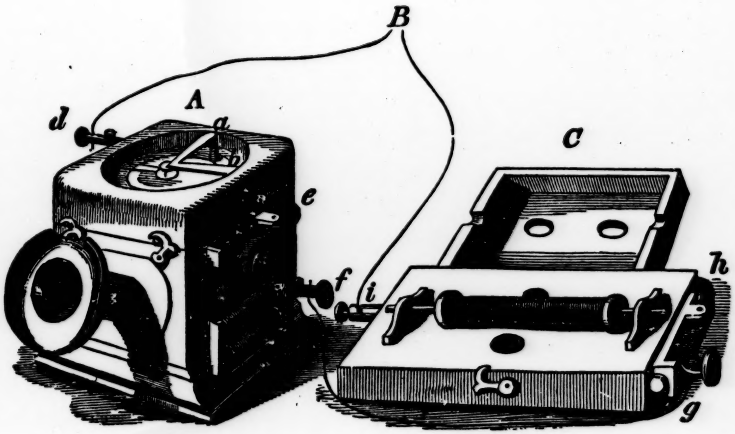
ALVESTO S. HOGUE,
Commissioner.

RETURN.

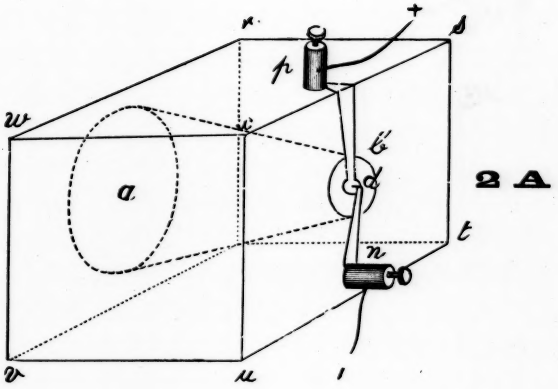
I, ALVESTO S. HOGUE, the Commissioner within named, do hereby certify and return to the Circuit Court of the United States of America for the District of New Jersey, that I have duly executed the within commission in manner and form as is therein and thereby commanded; and that the execution thereof will fully appear by the schedule to the said commission and the accompanying interrogatories annexed. I further certify that no one was present while the depositions were being taken, excepting myself, the within named commissioner, and George Fug, a clerk, employed by me to write the answers; and that the execution thereof will fully appear by the schedule to the said commission and the accompanying interrogatories annexed.

Given under my hand and seal this twenty-second day of December, A. D. 1886.

ALVESTO S. HOGUE,
Commissioner.

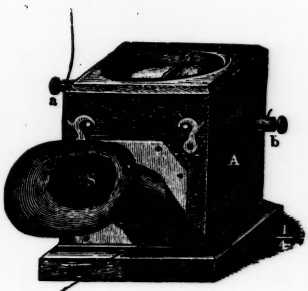


1A 1B



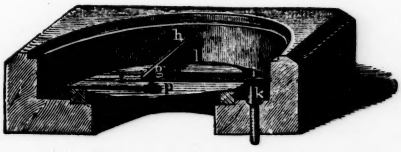
2 A

Fig. 348.



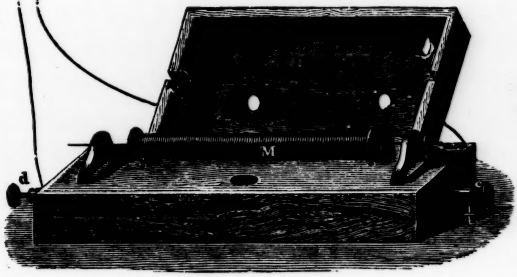
8 A

Fig. 349.

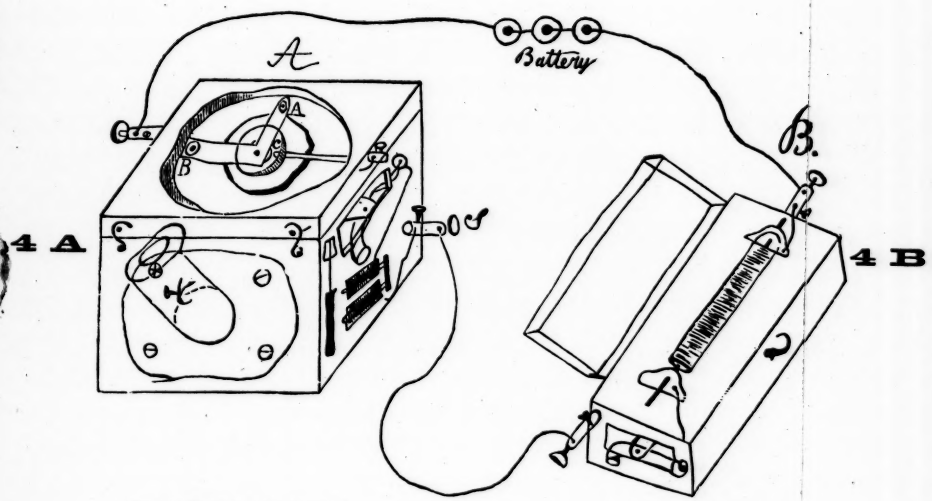


8 B

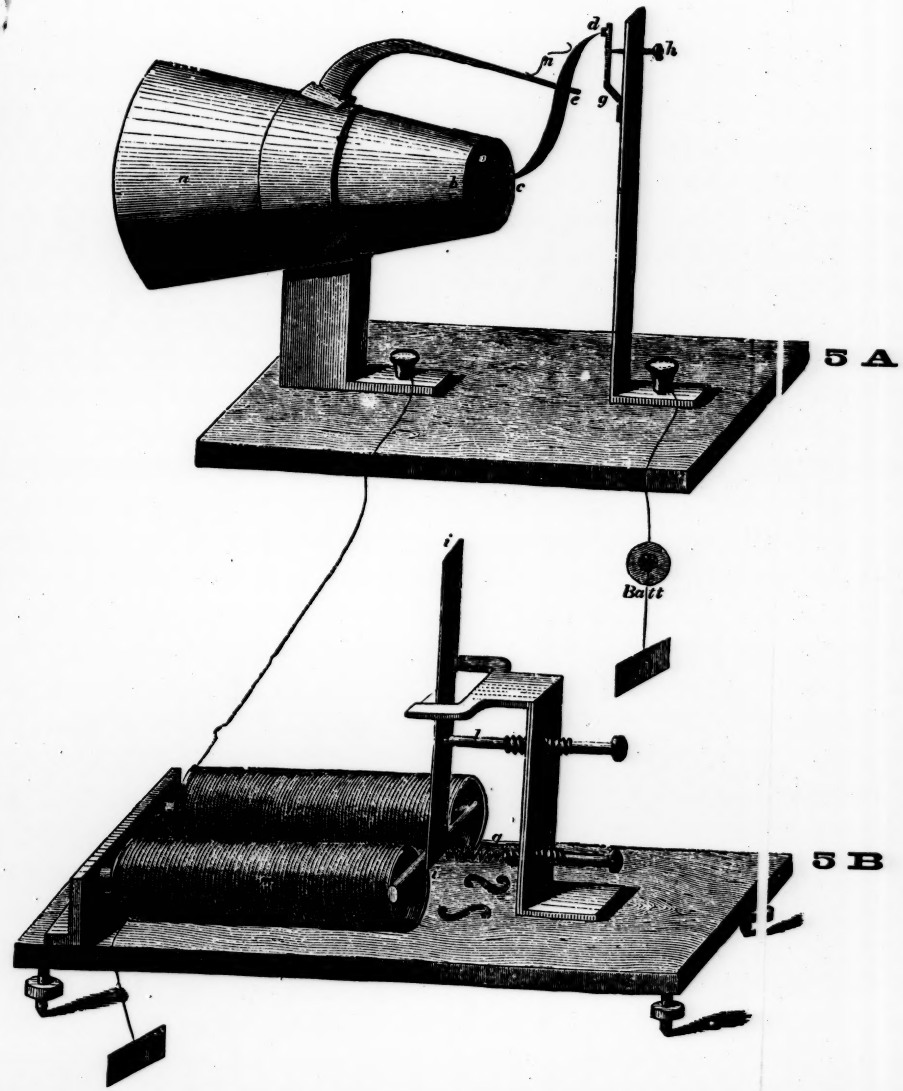
Fig. 350.



8 C



Reis's Telephonic Apparatus.—Facsimile of Drawing sent by Reis to Mr. Ladd.


d
h
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5 A
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UNITED STATES SUPREME COURT.

THE AM. BELL TEL. CO.

AGAINST

THE MOLECULAR TEL. CO.

A commission having been issued to take the testimony of Prof. Quincke, and that gentleman having declined to give his testimony :

It is now stipulated between the parties that the letter of said Prof. Quincke, published in Prof. Thompson's book, entitled Philip Reis, inventor of the telephone, pp. 112–113, may be read to the Court with the same force and effect as if sworn to by said Prof. Quincke in this case, without cross-examination, subject, however, to the same objections as made against the depositions of the other foreign witnesses, and that Prof. Thompson's account of that meeting may be also read to the Court as the same is contained in the 12th and 13th paragraphs, pp. 93 to 95 of that book, it being understood, however, that Prof. Thompson was not present on the occasion referred to, and that the facts stated by him were not within his personal knowledge.

The writings are annexed :

WHEELER H. PECKHAM,
Of Counsel for Molecular Tel. Co.,
and other defendants.

EDW. N. DICKERSON,
For Am. Bell Tel. Co.

"DEAR SIR:

"I was present at the Assembly of the German Naturalists' Association (Naturforscher Versammlung) held in the year 1864 in Giessen, when Mr. Philipp Reis, at that time teacher in the Garnier Institute at Friedrichsdorf, near Frankfort-on-the-Main, showed and explained to the assembly the Telephone which he had invented.

"I witnessed the performance of the instruments, and, with the assistance of the late Professor Boettger, heard them for myself.

"The apparatus used consisted of two parts, a transmitter and a receiver. The transmitter was a box, one side of which was furnished with a tube into which the speaking was to be done. At the top or the side of the box there was a circular opening, covered by a tympanum or membrane, upon which was fastened a piece of platinum. This piece of platinum was in communication with one pole of the galvanic battery. Over the membrane, resting upon the platinum, and in contact with it, was a piece of metal furnished with a platinum point, also in connection with one pole of the battery.

"The receiver consisted of a common knitting needle of steel, surrounded by a magnetizing coil of insulated wire, which also formed a part of the circuit, the whole resting on a resonant box.

"I listened at the latter part of the apparatus and heard distinctly both singing and talking. I distinctly remember having heard the words of the German poem, 'Ach! du lieber Augustin, Alles ist hin!' &c.

"The members of the Association were astonished and delighted, and heartily congratulated Mr. Reis upon the success of his researches in Telephony.

"(Signed,)

"DR. G. QUINCKE,

"Professor.

"Heidelberg, 10th March, 1883."

12. *Extract from the "Twelfth Report of the Upper-Hessian Association for Natural and Medical Science."* ("Oberhessische Gesellschaft für Natur und Heilkunde," Giessen, February, 1867.)

P. 155. Report the on doings and condition of the Association from the 1st of July, 1863, to the 1st of July, 1865, by Herr Gymnasiallehrer, Dr. W. Diehl.

* * * On the 13th of February (1864). "On the Tones of the Magnet, with Application to the Telephone, with experiments," by Professor Buff.

Exhibition of the Telephone to the Naturalists' Association of Germany. (Deutsche Naturforscher Versammlung.)

By far the most important of all the public exhibitions given by Reis of his Telephone, was that which took place on the 21st of September, 1864, at Giessen, on the occasion of the meeting of the German Naturalists' Association (Versammlung Deutscher Naturforscher). Here were assembled all the leading scientific men of Germany, including the following distinguished names, many of whom are still living: Prof. Buff (Giessen), Prof. Poggendorff (Berlin), Prof. Bohn (Frankfort-a-M., now of Aschaffenburg), Prof. Jolly (Munich), Dr. Geissler (Bonn), Prof. Weber (Göttingen), Prof. Plücker (Bonn), Prof. Qnincke (Heidelberg), Prof. Dellman (Kreutznach), Prof. Böttger (Frankfurt-a-M. and Mainz), Prof. Kekule (Bonn), Prof. Gerlach (Erlangen), Dr. J. Frick (Carlsruhe), Dr. F. Kohlrausch (Würtzburg), Prof. Reusch (Tübingen), Prof. J. Müller (Freiburg), Prof. Helmholtz (Heidelberg), Prof. Melde (Marburg), Prof. Kopp (Marburg), Prof. A. W. Hoffmann (London, now of Berlin), Mons. Hoffmann (Paris, optician), Hofrath Dr. Stein (Frankfurt-a-M.), Dr. W. Steeg (Homburg), Mons. Hartnack (Paris, and of Pottsdam), Prof. G. Wiedman (Basel, now of Leipzig), E. Albert (Frankfurt-a-M., mechanician), Dr. Thudichum (London), W. Schultze (York,

apothecary), Dr. J. Barnard Davis (Sheldon), E. J. Chapman (London, chemist), Dr. L. Beck, Prof. Charles J. Himes (U. S. A., chemist), E. W. Blake (New Haven, U. S. A., student), C. G. Wheeler (United States Consul in Nürnburg), and many others. Dr. C. Bohn (now of Aschaffenburg) was Secretary of the Association, and also secretary of the Section of Physics. The meetings of this Section were held in the labratory of Professor Buff. Reis came over from Friedrichsdorf, accompanied by his young brother-in-law, Philipp Schmidt. A preliminary trial on the morning of that day was not very successful, but at the afternoon sitting, when communications were made to the Section by Prof. Buff, by Reis himself, and by Prof. Poggendorff, the instrument was shown in action with great success. Reis expounded the story how he came to think of combining with the electric current interruptor a tympanum in imitation of that of the human ear, narrating his researches in an unassuming manner that won his audience completely to him; and the performance of the instrument was received with great applause. Various professors essayed to experiment with the instrument, with varying degrees of success according to whether their voices suited the instrument or not. Amongst these were Prof. Böttger and Prof. Quincke, of Heidelberg, whose account of the occasion is to be found on p. 112. Dr. Bohn, the Secretary of the Section, wrote for the "Journal" (Tagesblatt), issued daily, the following notice:

13. Extract from the report of the German Naturalists' Society, held at Giessen (1864).

"Afternoon sitting on the 21st September, 1864.

"Pro. Buff speaks about the tones of iron and steel rods when magnetised, and exhibits the corresponding experiments.

"Dr. Reis demonstrates his telephone, gives thereupon an explanation and the history of this instrument.

"Prof. Poggendorff produces tones in a metal cylin-

der, the slit-up edges of which touch one another firmly, and which is placed loosely round an induction bobbin, through which there goes an interrupted current."

(This occasion was the crowning point of Philipp Reis' career, and might have proved of even greater importance but for two causes : the inventors' precarious health, and the indifference with which the commercial world of Germany viewed this great invention. Where the keen insight of Reis contemplated the vast possibilities opened out by the invention of a new mode of inter-communication others saw only an ingenious philosophical toy, or at best a pleasing illustration of certain known principles of acoustic and electric science. And in spite of the momentary enthusiasm which the exhibition of the telephone had evoked the interest in it dwindled away. A few of the public journals of that date noticed the invention in eulogistic terms and spoke of the prospect it afforded of communication between distant friends and of simultaneous concerts being given in different towns, all transmitted telephonically from one orchestra. But the invention came too early. The public mind was not prepared to take it up, and the enthusiasm died away. Still in a few of the more important books on physics, acoustics and electricity, the matter continued to receive attention. In the well-known Muller–Pouillet's "Textbook of Physics" (Lehrbuch der Physik) edited by Professor J. Muller ; in the "Technical Physics" of Hessler, of Vienna, edited by Professsr Pisko ; in Pisko's "Recent Apparatus of Acoustics," and particularly in Kuhn's admirable "Handbook of Applied Electricity," the telephone was accepted as a definite conquest of science, and was described and figured. From the works named we transcribe the extracts which follow, and which sufficiently explain themselves.)

in the capacity of ex...

DEPOSITION OF CHARLES R. CROSS.

BOSTON, July 23, 1885.

Direct Examination by GEORGE L. ROBERTS, Esq., *of Counsel for Complainants.*

Int. 1. State your name, age, residence, and occupation.

Ans. Charles R. Cross; I am thirty-seven years old; I live in Boston, and am Thayer Professor of Physics in the Massachusetts Institute of Technology.

Int. 2. How long and to what extent have you been engaged in the study of the physical sciences, and to what extent, if at all, have you been accustomed to make experiments in the several branches of physics, especially those relating to electricity and acoustics?

Ans. I have been an instructor at the Institute of Technology during the past fifteen years, and during that time I have been constantly engaged in the study of various branches of physics. During the past eleven years I have especially investigated the subjects of acoustics and certain branches of electricity. In the prosecution of my studies during this time I have constantly been engaged in the experimental study of the subjects mentioned, and have been practically familiar with all the apparatus ordinarily used by scientific men in the investigation of sound and electricity.

Int. 3. What attention have you given to the speaking telephone, and to its principles and mode of operation?

Ans. I have been familiar with the rise and development of the speaking telephone from its very beginning, having been in frequent communication with Prof. Alexander Graham Bell ever since the winter of 1873–74. I am familiar with Mr. Bell's patents, have investigated with great care the theory upon which these patents are based, and am practically familiar with the construction and use of the various forms of instruments constructed in accordance with said patents. During the past six years I have conducted a very extensive series of experiments relating to the different branches of telephony, in the capacity of expert for the American Bell Telephone Company.

Int. 4. Have you given attention to that form of telephonic transmitter which operates by varying the resistance of a circuit?

Ans. During the last five years I have given special attention to the theory and operation of variable-resistance battery transmitters. I have made a large series of original experiments and investigations upon the subject, more extensive than any that I have ever seen in print. I have carefully studied the distinctions which exist between variable-resistance battery transmitters and circuit breakers, as well as the differences in the electrical and acoustic effects which they produce in the line wire and in the receiving telephone.

Int. 5. Have you heretofore testified as a witness in any cases in the courts of the United States, upon the principles of the inventions set forth in patents and embodied in machines or apparatus?

Ans. I have done so frequently.

Int. 6. You say you have been familiar with Mr. Bell's patents; state whether or not among these patents are those which have been introduced in evidence in this case marked "Exhibit Bell Patent No. 174,465," and "Exhibit Bell Patent No. 186,787."

Ans. The patents No. 174,465 and No. 186,787 are among those which I have had frequent occasion to examine.

Int. 7. Referring to the patent No. 174,465, will you explain the mode of operation of the apparatus referred to in the fifth claim of the patent, explaining, as far as may be necessary, the character of sounds, their action upon the apparatus, and the manner in which the apparatus operates to produce the results which are ascribed to it in the patent?

Ans. The sensation of sound is produced by the action upon the ear of the vibrating particles of air which are set into a vibratory or to-and-fro motion by the vibrations of the sounding body. The primary impulse given by the sounding body to those particles of air immediately in contact with it is gradually transmitted from particle to particle, in consequence of the elasticity of the air or other medium through which the sound passes. In consequence of the mode of action of the elasticity of the air, the motion originally communicated to the particles of air in contact with the sounding body is not transferred instantaneously to all [illegible] articles; but in consequence of their inertia, as the so[illegible] vibrates

to and fro, a similar movement is impressed upon one after the other of the particles surrounding it. This to-and-fro motion of the vibrating body generates a similar minute to-and-fro motion of the air particles, so that they are alternately crowded more closely together, and separated more widely from each other, thus producing alternate condensations and rarefactions in the air. It is to these alternate condensations and rarefactions that the term "sound wave" is given. It will be observed that each particle vibrates to and fro in a straight line in the direction in which the wave motion is propagated. If we consider that the vibration of the air particles is produced immediately by the vibration of the sounding body, we see that the motions of the air particles must be a perfect copy of the motions of the particles of the vibrating body. Such vibrations may differ in three separate ways; viz., in the extent of the path of the vibrating particle, in the frequency of its vibration and in the character of its vibration. It is evident, in the first place, that the vibrating particle may, in its to-and-fro motion, traverse a longer or shorter path; in the second place, it may traverse this path a greater or less number of times in each second, that is, its rate of vibration may differ; in the third place, while traversing its path it may move according to different laws of acceleration or retardation of its velocity; for example, its acceleration during a part of its course may be and in some cases is constant, or the rate of acceleration may constantly change, and the law of its change may vary in different ways. To the changes in the motion thus caused, what I have called the peculiar character of the vibration is due. If we consider these three kinds of variation in their effect upon the senses, we find that variations in the extent of the path or amplitude of vibration of the particle determine, other things being the same, the loudness of the sound; the variations in the frequency of vibration determine the pitch of the sound; and variations in the character of the vibration determine what is known as the quality or *timbre* of the sound.

In the statements which I have just made I have spoken of the motion of a single particle; but it is evident from the mode of transmission of sound that all of the particles of the air through

which the sound is conveyed partake of the various characteristics of vibration which I have discussed.

I have used the term "quality or *timbre*." Quality is that peculiarity of a sound by which, independently of its pitch or loudness, we are enabled to determine the instrument by which the sound is produced; thus, for example, the note of a violin differs from the note of a flute in quality, even though the two are the same in pitch and loudness.

It is well known to scientific men that these differences in quality, which, as I have said, are due to differences in the character of the motions of the vibrating particle, are produced acoustically by the combination of a number of separate or partial tones, which can be shown to be produced when a particle is in vibration, and which partial tones differ in number, in pitch and in intensity or loudness, in accordance with differences in the character of the motion of the vibrating air particles.

The lowest of these partial tones is called the "fundamental," the other and higher notes "overtones." Hence, it is evident that the quality of a sound depends upon the relative pitch, intensity and number of partial tones present. In a very few exceptional cases only the fundamental is present, and what is called a simple sound is produced. In general, the pitch of a note is determined by the fundamental, the overtones determining the quality.

I quote from a standard work on acoustics by Prof. W. F. Donkin, published, Oxford, 1870 (p. 11):—

"When we speak of the pitch of the note produced by a string or an organ pipe, we mean in fact, the pitch of the gravest simple tone in the combination. This particular component is in general louder than any of the others, and is that on which attention is fixed. The others become associated with it by habit, and seem only to modify its character without destroying the unity of its pitch."

These facts, constituting what is known as Helmholtz's Theory of Quality, were first discovered by the physicist whose name the theory bears, and were published by him more than twenty years ago. The human voice owes its peculiar quality to the presence of great numbers of these partial tones; and very slight changes in the partial tones will produce very considerable changes in the voice.

I quote from the English translation (Ellis's), published at London in 1875, of Helmholtz's great work "*Die Lehre von den Tonempfindungen*":—

"Human speech employs these very qualitative varieties of tone in order to distinguish different letters" (p. 28).

. . . . . .

"On inquiring to what external physical difference in the waves of sound the different qualities of tone correspond, we must remember that the amplitude of the vibration determines the force or loudness, and the period of vibration the pitch. Quality of tone can, therefore, depend upon neither of these. The only possible hypothesis, therefore, is that the quality of tone should depend upon the manner in which the motion is performed within the period of each single vibration" (p. 28).

. . . . . .

"Every different quality of tone requires a different form of vibration" (p. 32).

From what I have said thus far, it will be seen that, in order to reproduce articulate speech, we must be able to reproduce in the air, vibrations which shall possess the same characteristics of pitch, intensity and quality — that is, of rate of vibration, amplitude of vibration, and character of vibration — which are possessed by the vibrating particles of air which are set in vibration directly by the organs of speech. If we can determine the speed and direction of motion of an air particle at each instant, and hence also the extent of its path, we can evidently impress upon it all three of the characteristics that I have mentioned; and hence can produce any desired sound at will.

In Mr. Bell's patent No. 174,465 a method is described by which the motions which are produced in the air at one place, the transmitting station, can be reproduced by an electrical method of intercommunication at the receiving station. By means of his invention he is able, by the use of certain electrical apparatus, to impress upon the particles of air at a distant place, the receiving station, motions substantially identical with those which are immediately impressed by the voice upon the particles of air at the transmitting station.

According to the specification, he effects this result by the use of the transmitter, which takes up from the air at the transmitting sta-

tion the motions which are impressed upon it by the voice of the speaker, and the vibrating portion of which transmitter moves in substantial accordance with the movements of the air particles themselves. This transmitter, being connected with a line wire joining the two stations between which speech is to be transmitted, is enabled, by its electrical connection with that wire, to produce in it electrical variations which correspond to and are similar in form to the motions of the movable part of the transmitter, and hence to the motions of the air particles which have actuated the movable part of the transmitter. These electrical variations, in their turn, set in motion a movable part of a receiving instrument with which the line wire is connected, and, in their turn, produce in this movable part of the receiver, vibrations corresponding to and similar in form to those electrical vibrations by which they are produced, and hence to the motions of the air particles at the transmitting station. The movable part of the receiving instrument, thus vibrating, impresses upon the air at the receiving station, vibrations similar in form and corresponding to its own motions.

The motions thus produced in the air particles at the receiving station are therefore evidently similar in form and correspondent to the original vibrations impressed upon the air at the transmitting station by the voice of the speaker at that station. This being the case, it is evident, from what I have said, that the sound uttered by the speaker at the transmitting station will be reproduced at the receiving station.

It appears from these facts, that Mr. Bell's apparatus consists essentially of a transmitter adapted to take up the vibrations of the air at the transmitting station; a line wire connecting the transmitting with the receiving station, together with a battery or some other form of electrical apparatus which is capable of furnishing a supply of electricity, which line wire shall serve to transmit the electrical variations produced by the transmitter from one station to the other; and a receiver which, actuated by the electrical variations thus transmitted by the line wire, shall be caused to reproduce the motions of the transmitter and of the air particles by which that transmitter is actuated. It is true that the receiving instrument may not always reproduce the vibrations of the air particles at the

transmitting station in every minute detail, but the instrument is a speaking telephone only so far as it is adapted to reproduce those motions with substantial fidelity; and its practical construction and operation must be such that these vibrations shall be substantially reproduced.

It is evident that when the transmitter is in operation, variations in the electrical current may take place in three ways, — there may be a variation in either the direction of the current, the rate or violence of change of the current, and the frequency of change of the current; and from these three kinds of variations similar variations in the direction, rate and frequency of change of the motion of the movable part of the receiver will result. And hence, from these different electrical variations, differences in the quality, intensity and pitch of the sound produced by the receiving instrument will follow. Therefore, to reproduce articulate speech or any other sound in all its characteristics of pitch, intensity and quality, it is necessary that the movable portion of the receiving instrument shall be constantly under the guidance of and controlled by the movable portion of the transmitting instrument; and in case this constant control is not exercised, and in precisely that degree in which it ceases to be exercised, the instrument becomes incapable of transmitting articulate speech.

No form of transmitter which operates by making and breaking an electrical circuit can possibly transmit articulate speech or any other sound in its different characteristics of pitch, intensity and quality, for the reason that the constant control, of which I have spoken, is not exercised in such an instrument. With any circuit-breaking instrument the loudness and quality of the sound produced at the receiving station are dependent solely upon the physical construction and action of the receiving instrument itself, and of the battery or other source of electricity by which the transmitter is acted upon. The intensity and quality of the sound produced at the receiving station are, therefore, with such an instrument, entirely independent of the intensity and quality of the original sound produced at the transmitting station. It is for this reason that an instrument of this class, such as, for example, the well-known Reis instrument, operating in the manner described, is incapable of trans-

mitting either intensity or quality, and hence is incapable of transmitting articulate speech.

As will be seen from what I have already said, the Reis transmitter, or any other transmitter which operates by making and breaking the circuit, is capable of transmitting pitch, and pitch only.

I quote further, from the English translation (published 1875) of Helmholtz's great work: —

"*Pitch depends solely on the length of time in which each single vibration is executed, or*, which comes to the same thing, *on the vibrational number of the tone.* We are accustomed to take a second of time as the unit, and consequently mean by *vibrational number*, the number of vibrations which the particles of a sounding body perform in one second of time" (p. 17).

The essential difference between the electrical changes produced by the Reis transmitter and the changes produced by the apparatus, Fig. 7 of the Bell patent No. 174,465, when spoken to, is that the action of the Reis apparatus serves to break up into successive and disjunctive fragments a current of substantially uniform strength. This is a merely intermittent current. The frequency of its intermittences is the same as the frequency of the air vibrations which give rise to what is known as the pitch of the sound acting upon the transmitter. The apparatus, Fig. 7 of Mr. Bell's patent, on the other hand, produces when spoken to a series of electrical changes which in their character correspond to and substantially copy the changes which take place in the air performing the sonorous vibrations to be transmitted. The apparatus of Reis was intended to produce mere intermittences, the frequency of which corresponded to the pitch of the sound transmitted. The apparatus of Bell, on the other hand, was not intended to produce intermittences: nor is its operation due to their production. The declared purpose of the invention is to produce electrical variations, which in their form copy the vibrations of the air. This is the distinction between the mode of operation of one apparatus and the mode of operation of the other. It is the employment of the electrical changes due to and constituting one mode of operation as distinguished from the other, that is insisted upon by Mr. Bell in his patent and specified in his claim. It is because Mr. Reis employed the one mode of

operation that his apparatus is not a speaking telephone, and it is because Mr. Bell employed the other that his apparatus is.

There is also another reason which prevents a Reis transmitter or other circuit-breaking instrument from transmitting articulate speech; this is the effect of the interruptions of the current in producing a loud and disagreeable noise in the receiver, which of itself would be sufficient to overpower and obliterate those fine shades of variation upon which differences in quality depend.

In fact, this noise is so marked that an ordinary battery transmitter can be used as a telephonic call by so operating it as to cause it to actually make and break the electrical circuit. Under these circumstances, the noise which proceeds from the receiving instrument, which, when the transmitter is used in a normal and proper manner, can be heard only by one close to the instrument, is capable of being heard throughout a large room.

Int. 8. You have described the operation of a speaking telephone apparatus when transmitting speech as set forth in the specification of Mr. Bell's patent, No. 174,465. Will you now state briefly what is the function and importance of the similarity between the vibrations of the air accompanying sounds uttered into the transmitter and the electrical undulations which are caused in the apparatus while transmitting speech, as particularly referred to in the fifth claim of Mr. Bell's said patent, which is as follows: —

"5. The method of and apparatus for transmitting vocal or other sounds telegraphically, as herein described, by causing electrical undulations similar in form to the vibrations of the air accompanying the said vocal or other sounds, substantially as set forth"?

Ans. It is because of this similarity that speech is transmitted. In a perfect instrument the motions of the receiver are both the effect and a copy of these electrical variations. Since these electrical variations are a copy of the motions of the transmitter, it follows that the motions of the receiver are a copy of those of the transmitter; if substantially this action takes place, speech is transmitted, otherwise speech is not transmitted.

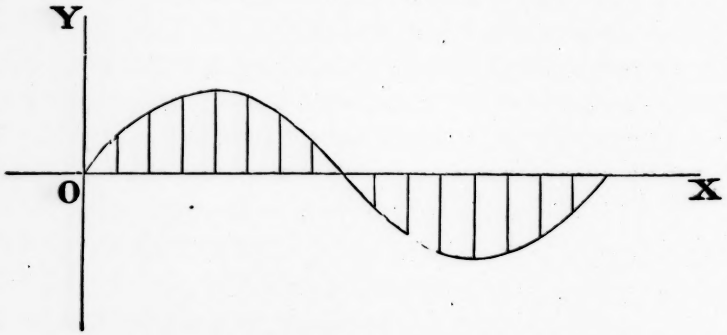
Int. 9. You speak of the sound waves, and explain the mode in which they are produced. Do you understand that the actual exist-

ence of these sound waves has been demonstrated, or is accepted as a fact by scientific men?

Ans. The existence of such sound waves has been accepted as a fact by scientific men for several hundred years. Within a few years past they have been visibly shown to exist, by a method which demonstrates the existence of alternate condensations and rarefactions to the eye.

Int. 10. Has any method of representing such waves been adopted; and if so, what is it?

Ans. It is customary among physicists to represent the motions of the particles of a sound wave, and also the variations in condensation and rarefaction at different points in a sound wave, by a graphical method. I can best illustrate this by reference to a diagram which I produce, to be incorporated in my answer.



The curve in the diagram is what is called a sinusoidal curve, such as corresponds to the sound waves produced by a simple sound, consisting of a single note without overtones. Such a sound can be produced by a tuning fork, mounted on a resonant case, and bowed in a manner suitable for this purpose. O X is divided into a number of equal spaces, to represent equal periods of time. The length of these spaces is purely arbitrary. The distances from O to the beginning of any one of these divisions are called *abscissas*. From each of these points on O X, representing successive intervals of time, lines are drawn parallel to O Y, and proportional in their relative lengths to the distances of the particle from the point of rest at the successive periods of time.

In the case of the particle pursuing a simple vibration, these magnitudes will increase to a maximum, which will be attained at the instant when it reaches the extremity of its path; they will then diminish as it comes back to the starting point; and as it passes beyond it, moving in the other direction, they will be indicated by distances measured off below the line O X. Joining then the extremities of the perpendicular lines, we obtain a broken line somewhat resembling a curve; and if we put the perpendicular lines close enough together, the broken line joining their extremities becomes a curve. This curve is determined by the length of two sets of lines or distances, — the *abscissas* measured on O X, and the *ordinates* measured parallel to O Y. In the case stated, the starting point is assumed to be in the middle of the path (*e. g.*, the position of a pendulum when at rest), and the motion is measured in both directions from it; *i. e.*, the curve is on both sides of the line, and part of the ordinates have one direction, part the other. But the point from which the measurements are taken is purely arbitrary; and the line O X, which represents this point, might be placed lower down and tangent to the lowest part of the curve. In that case the curve would not change its character, but the ordinates would all be measured in one direction and on one side of O X. Algebraically expressed, they would all be + quantities, instead of being alternately + and — quantities, in the two branches of the curve; only the + quantities would be greater than shown in the diagram. In the case indicated by the diagram, we should consider that an increase in the length of the ordinates, in passing from one to the next, signified motion in one direction, and a decrease signified motion in the other direction. In this method of representation one set of lines, measured along O X, corresponds to the period in which the movement is executed, or its frequency; and the other measured along O Y, to the amplitude or extent, and also to the direction of the motion; and these measurements express frequency, amplitude and direction. The same curve will represent the extent of rarefaction and of condensation of the air produced by the movement of the particles, and also, when correctly interpreted, the motion and the varying velocity of the particles.

It is from this habit of graphical expression that a vibration is

commonly spoken of among physicists as having "form"; form of vibration is a phrase used to signify the "character" of a vibration, as I have explained it.

It must be remembered that this curve does not represent the path of the moving particle; that always moves to and fro in a straight line. This curve is merely a convenient form of expressing to the eye the character and variation of the motion.

I quote again from the work of Helmholtz: —

"To render the law of such motions more comprehensible to the eye than is possible by lengthy verbal descriptions, mathematicians and physicists are in the habit of applying a graphical method, which must be frequently employed in this work, and should therefore be well understood" (p. 29).

The writer then describes the method of drawing acoustic curves, and continues: —

"Physicists, then, having in their mind such curvilinear forms representing the law of the motion of sounding bodies, speak briefly of the *form of vibration* of a sounding body, and assert that *the quality of tone depends on the form of vibration*" (p. 32).

. . . . . .

"I have by no means unfrequently found even physicists start on the false hypothesis that the vibrational form must exhibit little waves corresponding to the several audible upper partial tones" (p. 53).

. . . . . .

"The reader must bear in mind that when we apply the term 'compound' to the vibrations produced by a single musical instrument, the 'composition' has no existence except for our auditory perceptions or for mathematical theory. In reality, the motion of the particles of the air is not at all compound; it is quite simple, flowing from a single source" (p. 189).

Int. 11. If you can produce from any scientific work a diagram representing the manner in which overtones are combined with a fundamental to give quality to sound, different from that due to the fundamental alone, and representing the form given to the curve as the result of all the vibrations, will you do so, stating the source from which you derive it, and explaining, as far as you think necessary, the diagram?

Ans. The following diagram, taken from "Mayer on Sound," p. 153, represents the motion of a particle under the influence of sound waves: —

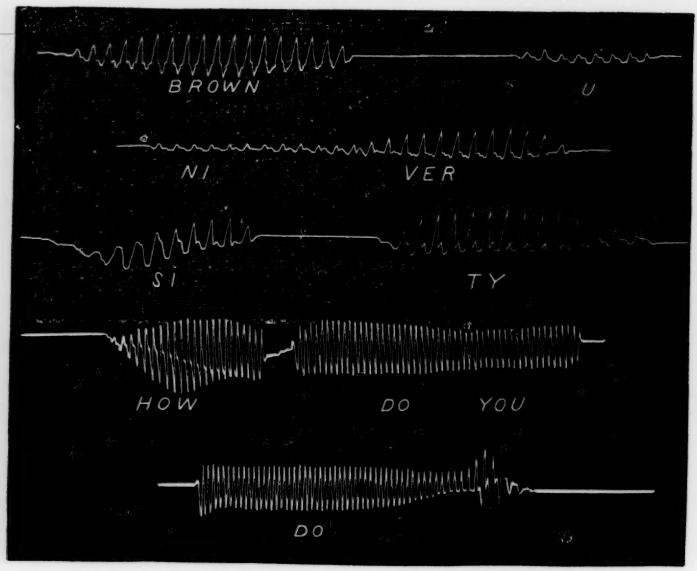
The curves at *a b* represent six sound waves of six simple sounds. When these are sounded together as fundamental and overtones, and with relative intensities corresponding to the amplitude of the curves, as drawn, so as to produce a sound having the quality due to this combination, the vibrational "form," as it is called, of the sound perceived by the ear is represented by the curve at *c d*. The set of vibrations which constitutes one complete vibration is shown twice between *c* and *d*. The entire "form" or character of this curve can be determined and controlled, as already stated, by determining or controlling for each point, the length of the abscissa and of the ordinate for that point, or in other words, determining or controlling, the elements of time or frequency, amplitude or intensity and direction; but it is obvious that it will require very many measurements of abscissas and ordinates to determine or control the "form" of each complete set of vibrations.

The curve representing one set of vibrations is about three inches long; and it is apparent, even to a casual observer, that by taking the ordinates as little as one eighth of an inch apart, we should miss the little twists, which most strikingly represent to the eye the "quality" or the effect of the overtones in this vibrational form, and which are equally important to the "quality" of the sound as per-

ceived by the ear; and, as in the articulate speech of a woman, there are twenty-four thousand of these *complete* sets in a minute, it will be obvious that in order to reproduce this vibration the control must be exercised, not merely twenty-four thousand times a minute, but really without any interruption or cessation whatever.

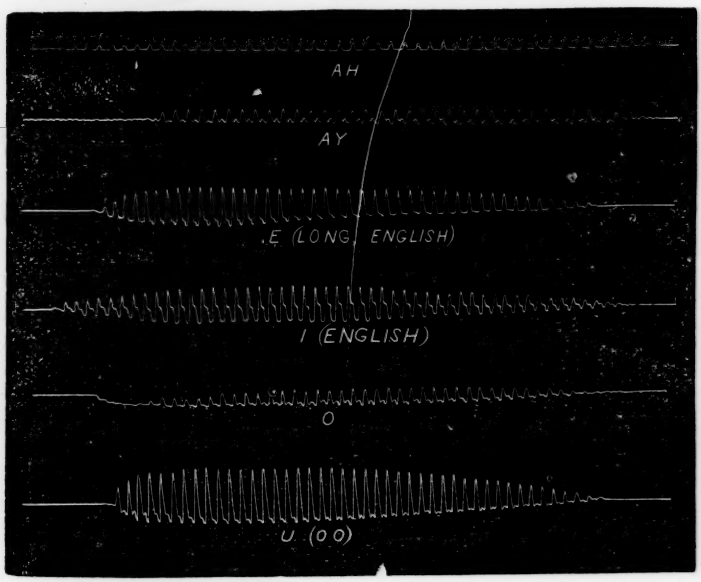
Int. 12. If observations have been made upon the curves produced by spoken words, and you can produce a diagram representing the results of such observations, will you do so, giving the authority from which they were made?

Ans. The minute changes which take place during articulation are well shown in a series of curves made by Prof. E. W. Blake,



Jr., of Brown University, and described in *Silliman's Journal* for July, 1878. These curves were produced by reflecting a ray of light from a mirror so attached to the plate of a speaking telephone that the vibrations of this plate were communicated to the mirror. The reflected ray is caused to act photographically upon a sensitized plate of glass, the mirror at the same time being caused to vibrate by the action of the voice upon the telephone plate. On rapidly moving the plate of glass in a direction at right angles to

that in which the reflected ray was caused to vibrate by the vibrations of the mirror, a photographed representation of the complex vibrations of the mirror was produced.



In Prof. Blake's figures the vibrations characteristic of different vowels, and the rapidly changing vibrations produced in the case of a spoken sentence, are very beautifully shown. According to the statement made by Prof. Blake in the article referred to, the vibrations are magnified in the accompanying cuts one hundred and twelve times. Notwithstanding the accuracy of Prof. Blake's drawings, the mere thickness of the lines in the woodcut is sufficient to obliterate many of the more delicate variations in those vibrations which characterize articulate speech.

Int. 13. Referring again to the first Bell patent, No. 174,465, to which your attention has been called, will you state what the moving parts are which you have referred to as being put in motion by sound waves, or by variations of currents produced by sound waves?

Ans. In Fig. 7 the transmitter possesses a movable armature, *c*, one end of which is hinged, while the other is so attached to a mem-

brane at *a* that when this membrane is set in vibration by the utterance of a sound into the cone A, the armature shall be caused to take up the vibrations of the membrane. By the vibration of this armature, as it approaches nearer to or recedes from the pole of the electro-magnet *b*, in accordance with the well-known laws of magneto-electric induction, electrical undulations or waves are produced in and transmitted by the line wire *e*. The receiving instrument which is in electrical connection with the line wire possesses an electro-magnet *f*, whose magnetic strength varies in accordance with the electrical variations produced in the line wire in the manner described. In front of this electro-magnet of the receiver, and opposite its pole, is a vibratory armature of inductive metal, hinged at *k*, and connected at *i* with a membrane stretched over the larger end of the cone L, so that variations in the magnetic strength of the electro-magnet *f*, produced by electrical variations in the line wire *e*, produce variations in the armature *h*, and consequently in the attached membrane, so that this attached membrane vibrates in correspondence with the motions of the membrane of the transmitting instrument, and therefore in correspondence with the vibrations of the voice by which the membrane of the transmitter is actuated. I should have said that the vibrating armatures of both the transmitting and receiving instruments are of iron or other inductive metal; and I would also call attention to the fact that the hinged end of each of these vibratory armatures is in magnetic connection with that pole of the electro-magnet which is farthest from the vibrating part of the armature itself; this mode of connection serving to increase to a certain degree the magnetic strength of the apparatus.

Int. 14. Will you explain a little more in detail the functions of the battery represented in Fig. 7 of the Bell patent of which you have been speaking, and the manner in which the undulations in the current are produced in the apparatus represented in that figure, and in what way the undulatory current acts in the receiving instrument to produce the proper results?

Ans. The magnets *b* and *f* in Fig. 7 are electro-magnets, having soft iron cores, which cores are magnetic only when a current of electricity is passing through the coils surrounding them. The object of the battery shown in Fig. 7 is simply to produce this cur-

rent, which shall cause the cores to be kept magnetized. The armature *c* of the transmitter, which is of iron or other inductive metal, will, as it moves to and fro, alternately increase and diminish the magnetic strength of the magnet *b*. These variations of magnetic strength will correspond to the various changes in motion of the vibrating armature. In accordance with the well-known laws of magneto-induction, as discovered by Faraday, every change in the magnetic strength of the core of the electro-magnet *b* will produce corresponding changes in the current of electricity which passes through the line wire *e*. These variations in the strength of the current will cause corresponding variations in the magnetic strength of the electro-magnet *f*, and these variations in the strength of the magnet will act immediately upon the vibratory armature at *h*. An increase of strength in the magnet *f* will cause the armature to approach to the magnet, while diminution of magnetic strength will allow the armature, under the influence of the tension of the membrane to which it is attached, to recede farther from the pole *f*. Hence, under the influence of the varying magnetic strength of *f*, the vibratory armature at *h* will execute vibrations corresponding to these changes in magnetic strength, and therefore corresponding to the changes in the electric current in the line wire *e*, to the changes in the magnetic strength of the magnet *b*, and therefore corresponding to the variations in the motion of the vibratory armature at *c*, when moved by the vibrations of the membrane with which it is in contact. The membrane of the receiving instrument at *i* will therefore vibrate in correspondence with the membrane *a* of the transmitting instrument.

Int. 15. Please state briefly the principal scientific facts which you find set forth, and correctly set forth, in Mr. Bell's patent No. 174,465, of March 7, 1876, with reference to the apparatus shown in Fig. 7, and its operation, and which bear upon the question whether the patent, so far as that apparatus is concerned, is a patent for an electrical speaking telephone.

Ans. The speaking telephone is shown in Fig. 7 of the patent. In the body of the specification and in the claim, the patentee describes the nature of the operation which will take place when a sound is uttered into the transmitter by the human voice. I know,

as a matter of scientific knowledge, that when spoken to this is the kind of operation which it theoretically will perform, and the only kind of operation which it theoretically can perform.

The patentee then asserts the consequence of that operation with that apparatus to be that a similar sound to that uttered into the transmitter is then heard to proceed from the receiver. This action is theoretically the necessary consequence of this operation of the apparatus. I know from actual trial, that this operation would be so well performed by a set of instruments constructed according to the instructions of the patent, and without further invention, that the listener at the receiving end will recognize and understand the words spoken at the transmitting end.

That feature to which the most prominence is given in the specification is the similarity of form between the sound vibrations which actuate the instrument and the electrical undulations due to them. This is expressly mentioned in the following sentences of the specification: "These undulations are similar in form to the air vibrations caused by the sound — that is, they are represented graphically by similar curves."

This is the only feature specifically mentioned in the claim, which reads as follows: —

"5. The method of, and apparatus for, transmitting vocal or other sounds telegraphically, as herein described, by causing electrical undulations, similar in form to the vibrations of the air accompanying the said vocal or other sounds, substantially as set forth."

This feature of similarity in form between the electrical undulations and the air vibrations producing them secures the transmission of quality. It has no purpose, function or effect, except the transmission of quality, which includes articulate speech. This correspondence of form is the essential electrical novelty which distinguishes this apparatus from all others known to the community before it.

Int. 16. Do you find any mode suggested in the patent as an alternative one to that you have described, of producing the variations or undulations in the current between the transmitter and receiver; if so, will you quote from the specification the language which refers to such other mode?

Ans. It was well known to electricians, long before the date of Mr. Bell's first patent, that the strength of an electrical currrent can be varied, either by increasing the electro-motive force of the source of electricity or by diminishing the resistance of the circuit, and conversely, in accordance with the well-known law of Ohm,

$$\text{Strength of Current} = \frac{\text{Electro-motive Force}}{\text{Resistance of Circuit.}}$$

In the apparatus which I have described, Mr. Bell explains a mode of producing these electrical undulations by varying the electro-motive force. He also clearly recognizes the possibility of producing such undulations by varying the resistance of the circuit. In his specification No. 174,465, I find the following:—

"Electrical undulations may also be caused by alternately increasing and diminishing the resistance of the circuit. . . . The internal resistance of a battery is diminished by bringing the voltaic elements nearer together, and increased by placing them farther apart. The reciprocal vibration of the elements of a battery, therefore, occasions an undulatory action in the voltaic current. The external resistance may also be varied For instance, let mercury or some other liquid form part of a voltaic circuit, then the more deeply the conducting wire is immersed in the mercury or other liquid the less resistance does the liquid offer to the passage of the current. Hence, the vibration of the conducting wire in mercury or other liquid included in the circuit occasions undulations in the current. The vertical vibrations of the elements of a battery in the liquid in which they are immersed produces an undulatory action in the current by alternately increasing and diminishing the power of the battery."

Int. 17. If electricians have been in the habit of stating, in algebraic terms, the law to which you have referred, will you give the form of expression which has been used, explaining the symbols, and state how long that law has been known, and whether or not it is one which has been found of use in the practical application of electricity?

Ans. The law of Ohm is usually expressed by a formula $C = \frac{E}{R}$, in which C is the strength of the current; E the electro-motive force, that is, the force producing the current; and R the total resistance of the circuit. Ohm's law was, if I recollect rightly, first stated by him in the year 1827. For the last thirty years its importance has been fully recognized by physicists, and it has been applied by

constructors of electrical apparatus in determining the dimensions and arrangement of the different parts of such apparatus.

Int. 18. In your judgment, does the substitution of one of these ways of varying the current for the other substantially change the character of the described apparatus as an apparatus for transmitting sounds, or substantially change the method by which sounds are transmitted or reproduced.

Ans. Speaking as a scientific man, I should say that it does not.

Int. 19. Have you examined and tested the instruments marked "Exhibit Defendants' Transmitter" and "Exhibit Defendants' Receiver" in this case? If so, for what purpose do you find them to be adapted, and what has been the result of your tests with them?

Ans. I have examined and tested the instruments referred to, namely, Exhibit Defendants' Transmitter and Exhibit Defendants' Receiver, and I find that they are, from their construction and method of operation, adapted, when suitably connected with a battery, to transmit articulate speech. I have, in fact, so connected them, and transmitted articulate speech by means of them.

Int. 20. When so connected and used for that purpose, what substantial likeness, if any, does the apparatus thus constituted, and the method by which it operates to transmit speech, bear to the apparatus and method described in the patent to Bell of which you have been speaking, and referred to in the fifth claim thereof? And in making this comparison, state whether or not in your judgment the defendants' said instruments, when so used, embody the invention described in said patent and referred to in said claim.

Ans. The apparatus to which I have referred in my last answer, Exhibit Defendants' Transmitter and Exhibit Defendants' Receiver, when connected and so operated as to transmit articulate speech, uses the method invented by Mr. Bell, and described in his specification No. 174,465, for transmitting vocal or other sounds telegraphically, by causing electrical undulations similar in form to the vibrations of the air accompanying such sound. The instruments in question most certainly embody the invention which Mr. Bell describes in his specification referred to, and when used in the transmission of articulate speech constitute an apparatus which is sub-

stantially that described by him in his said patent in connection with Fig. 7 of the drawings and referred to in the fifth claim.

Int. 21. In the operation of transmitting speech in the defendants' apparatus, what is the importance of causing the electrical undulations to be similar in form to the sound waves?

Ans. Precisely the importance which is indicated in my answer to Int. 8. Any departure from similarity impairs the character of the speech to the extent to which it occurs; and when that departure or any extraneous disturbance reaches a certain point the sounds at the receiver cease to be intelligible as speech.

Int. 22. Will you compare these instruments, when so connected and used, with Mr. Bell's apparatus, to which you have referred, pointing out the functions and mode of operation of the several parts? And if you find that these instruments differ specifically from the Bell apparatus, explain the nature of the differences, and give your judgment as to their affecting the substantial likeness of this apparatus to the Bell apparatus and its method of operation.

Ans. In Mr. Bell's patent No. 174,465, I find a transmitting instrument, a receiving instrument, a line wire connecting these and a battery or other source of electricity. In the apparatus described, the transmitter possesses a movable part, which is capable of being set in vibration by the agency of the voice. This movable part is so arranged that it shall cause electrical variations in the current traversing the line wire. The receiver is so arranged that the variations of current referred to shall communicate motion to a movable part, which shall in its turn communicate motion to the air about it. As I have already shown at some length, the vibrations of this movable portion, when actuated by the sound waves produced by the voice, correspond to these in form, and by their action upon the receiving instrument cause it to vibrate in a similar manner, and hence produce corresponding vibrations in the air about the receiver. The function of the transmitter, it is evident, is simply to produce in the line wire electrical undulations similar in form to the vibrations of the air particles through whose agency they are produced. The function of the receiver is simply to translate, so to speak, the electrical undulations produced by the transmitting instrument and conveyed to the receiving instrument by the line wire, into vibrations of

the air at the receiving instrument. Mr. Bell indicates that these electrical undulations may be produced either by varying the electromotive force of the current or by varying the resistance of the circuit.

In the exhibits specified I find a transmitter and a receiver, which when placed in electrical connection with each other by means of a line wire, and provided with a battery as a source of electricity, are adapted to transmit, and will transmit, articulate speech from one station to another.

In the defendants' battery transmitter I find an instrument, which, from its construction, is adapted to produce, and when properly operated by the voice, will produce, electrical undulations in the current traversing the circuit, similar in form to the air waves by which these electrical variations are produced.

In the defendants' receiver I find an instrument which is adapted to produce vibrations in the air similar in form to vibrations originally produced in the air at the transmitting station by the voice, as I have already explained. The defendants' apparatus, like the apparatus of the patent to Bell, contains a transmitter, which, from its construction, is adapted to produce electrical undulations as described, and a receiver which is adapted to retranslate these electrical undulations into vibrations of the air.

The defendants' battery transmitter adopts one of the modes mentioned by Mr. Bell as suitable for the production of electrical undulations similar in form to the air waves produced by the voice, namely, by varying the resistance of the circuit. The precise means adopted in the defendants' transmitter for varying the resistance of the circuit is different from the particular means referred to by Mr. Bell, inasmuch as it utilizes the property, possessed by various substances, of variation in resistance with variation in pressure.

In my opinion, however, the adoption of one rather than another particular way of varying the resistance of the circuit does not materially affect the substantial likeness of the apparatus of Mr. Bell and defendants, or its method of operation.

Int. 23. Will you state whether the fact to which you refer, that the resistance of substances may be varied by pressure, was one

known before the date of Mr. Bell's patent, and recognized in the construction of electrical apparatus; and if you can refer to any electrical works of authority, where this fact is referred to, will you do so, and quote the references to the fact?

Ans. It was known long before the date of Mr. Bell's patent that the resistance of a circuit is varied, without being broken, by variations in the intimacy of contact or amount of pressure between two electrodes in contact, from one to the other of which a current is passing. This fact was noted and recorded by Du Moncel in his book, "Applications de l'Électricité," Vol. I. p. 246, edition of 1856, published at Paris in that year. In the "Comptes Rendus" for July, 1874, a communication from the same writer described some experiments as to the resistance offered to the current in passing from one electrode to another, in the case where one was a good conductor and the other a poor conductor, and showed that a moderate increase of pressure at the contacts would materially increase the conductivity, and thereby the current; and he gave his explanation for his phenomenon.

In Du Moncel, "Applications de l'Électricité," ed. 1856, Vol. I. p. 246, I find the following: —

"Une chose assez curieuse, et qui paraît être au premier abord en contradiction avec la théorie que l'on s'est faite de l'électricité, c'est que la plus ou moins grande pression exercée entre les pièces de contact des interrupteurs influe considérablement sur l'intensité du courant qui les traverse. Cela tient souvent à ce que les métaux de l'interrupteur ne sont pas toujours dans un état parfait de décapage au point de contact, mais peut-être aussi à une cause physique encore mal appréciée. Ce qui est certain, c'est que, dans les interrupteurs où la pièce mobile de contact est sollicitée par une force extrêmement minime, le courante éprouve souvent des affaiblissements assez notables pour faire manquer la réaction électrique qu'on attend d'eux."

Which I translate as follows: —

"A somewhat curious fact, which at first sight appears to be in contradiction to the views ordinarily received as to the action of electricity, is that the greater or less pressure exercised between the contact pieces of interrupters has an important influence upon the strength of the current which traverses them. This often happens, because the metal of the interrupter is not perfectly free from rust

at the point of contact, but perhaps also because of a physical cause as yet but little appreciated. This is certain, that with interrupters in which a movable contact piece is acted upon by a very slight pressure, the current often suffers such an enfeeblement as to cause a failure in the electrical action which was expected."

The same writer describes, in the "Comptes Rendus" for July 6, 1874, a series of experiments in which he measured the current in a circuit, part of which consisted of a platinum electrode and a piece of wood, more or less damp, kept in constant contact, but with varying pressure, and says, p. 41, in an article entitled "Récherches sur les transmissions électriques à travers les corps ligneux," as follows: —

"Les expériences que j'avais à faire pour avoír une constation exacte des effets produits, étaient assez délicates, car une foule de causes étrangères peuvent intervenir, et changer les résultats fournis. Ainsi le dégré de serrage des plaques métalliques de communication avec le bois, son isolement plus ou moins parfait du sol et des murs de l'appartement, où l'on expérimente, la grandeur des surfaces mises en communication avec le circuit métallique, la masse du bois, l'état plus ou moins humide de l'air du cabinet des expériences, le contact fortuit des doigts sur les fils de communication avec le galvanomêtre, et l'état d'isolement de ces fils sont autant de causes qui peuvent modifier les résultats que l'on obtient.

. . . . . .

"6. Que le dégré de la pression de la plaque de platine contre le bois a tellement influé sur l'intensité du courant ainsi transmis, qu' étant de 12 dégrés avec un serrage maximum elle est devenue à zéro quand la plaque était abandonée à son propre poids, et à 5 dégrés seulement avec un faible serrage."

This I translate as follows: —

"The experiments that I have had to make in order to have an exact proof of the effects produced were very delicate, because a number of foreign elements might enter and change the results. Thus *the amount of pressure upon the metallic plates in communication with the wood*, its more or less perfect insulation from the earth or the walls of the room, the size of the surfaces put in communication with the metallic circuit, the mass of the wood, the greater or less humidity of the air of the experimenting room, the accidental contact of the fingers with the wires leading to the galvanometer, and the condition of the insulation of these wires, were causes which might modify the results that would be obtained.

. . . . . .

"6. That the amount of the pressure of the platinum plate against the wood has so much influence on the strength of the current thus transmitted, that from twelve degrees, with a maximum pressure, it became reduced to zero when the plate was pressed only by its own weight, and to five degrees only with a slight pressure."

In Du Moncel's "Traité de Télégraphie Électrique," Paris, 1864, Part IV. p. 559, in speaking of apparatus designed to establish electrical contact, the author says: —

"L'expérience montre que plus la pression des contacts est grande, plus est énergique l'intensité du courant qui les traverse."

That is, in English —

"Experiment shows that the greater the pressure of the contact pieces, the stronger is the current passing through them."

That fact was also constantly acted upon in the practical use of electrical apparatus; care was always taken that contacts should be firm and with considerable pressure, for otherwise the full and desired strength of current was not obtained.

Int. 24. State more particularly what you have meant by variations in pressure, as applied to the defendants' apparatus, and as applied to the experiments and statements of Du Moncel, which you have quoted.

Ans. By the variations in pressure which I have mentioned, I mean those variations because of which the contact pieces of hard carbon and platinum in the transmitter are pressed more or less closely together. I do not refer to these variations of pressure as producing change throughout the whole mass of the contact pieces, but simply to those variations which occur at the surfaces in contact. These are simply variations in the force by which the contact pieces are pressed together; and such variations produce variations in the electrical resistance of the joint thus made. The greater the pressure the more intimate is the contact and the less the electrical resistance, and *vice versa*.

Int. 25. What name has been given to that part of a battery telephone which is made to operate by variations in pressure between

contact pieces of carbon or other conductor, and what familiar instance of such a telephone can you mention?

In this connection, also, you may further explain the principle of its operation.

Ans. That variety of the speaking telephone transmitter which is referred to in the question is known as the articulating microphone, or, more generally, simply as the microphone. The form best known in commercial use is what is called the "Blake transmitter," invented by Mr. Francis Blake, and manufactured for general use by the Bell Telephone Company in the fall of 1878, and now universally employed in the United States.

The microphone consists physically of two electrodes placed normally in contact, with a slight pressure, and forming part of a circuit supplied with a current from a battery. A single Leclanché cell is generally employed in practice, though in some of my experiments with certain forms of microphone having large contact surfaces I have used as many as four Leclanché cells or two Bunsen.

One of the electrodes of the microphone is so arranged that when spoken to it will take up the vibrational movement of the sound waves. The other electrode is mounted so as not to be similarly affected by them; and the consequence is that the former electrode moves relatively to the latter. This motion of one electrode relatively to the other is excessively minute; but it is sufficient to so affect the current in the circuit that a magneto-receiver of the ordinary improved commercial form, conforming to the principles indicated by Fig. 7 of Mr. Bell's first patent, will audibly repeat the words uttered into the transmitter.

To aid in this operation of the transmitter, the electrode which is designed to be more directly vibrated by the voice is preferably made of such a shape as to offer itself some of considerable surface to the sound waves, or else is mounted upon an extended surface, such as a metallic diaphragm or a thin board.

There seems to be hardly any limit to the forms which may be given to the microphone. Many materials, including the ordinary metals, can be used for the electrodes; but it has always been the practice to make one of them at least of carbon, because this material gives far better results than any other hitherto used. In the

Blake transmitter, one electrode is a hemisphere of platinum about $\frac{1}{20}$ of an inch in diameter, slightly flattened, while the other offers a plane surface of hard gas carbon, artificially hardened and polished.

The back electrode, or anvil electrode, as it is sometimes called, is either rigidly held or is more often so mounted that it can yield somewhat, but not too readily, to the motions of the electrode directly acted on by the voice. The desired normal contact and pressure in the latter case are commonly obtained by the use of a spring or by gravity and sometimes in other ways.

A speaking telephone on this principle was described in papers filed in the Patent Office by Mr. Berliner, and by Mr. Edison, in 1887. In 1878, Prof. Hughes reinvented it, approaching the problem from a somewhat different direction, viz., from vibrations mechanically excited by scratching with a pencil, or by the tramp of a fly, and passing thence to those excited by sonorous waves in the air. He first published a description of his instrument in a paper read before the Royal Society, London, May 9, 1878. Notices of it are to be found in the *Scientific American* Supplement, June 8, 1878, and elsewhere.

The action of the microphone in transmitting articulate speech is as follows: The sound waves produced by the voice impress their vibrations directly upon the front or "hammer" electrode, and by virtue of the inertia of the back or "anvil" electrode, as already explained, the vibrations of the first electrode cause corresponding variations in pressure between it and the second electrode. These variations of pressure, by varying the electrical resistance of the microphone contact, create electrical undulations in the current similar in form to the sound waves producing them; and when these electrical undulations pass through the coils of the electromagnet of the receiving telephone they cause corresponding variations in the magnetic state of the core, and thus set the diaphragm into vibrations corresponding to such magnetic changes. By these vibrations of the diaphragm air waves are finally produced at the receiving station similar in form to those originally produced by the voice of the speaker at the transmitting station.

***Int.* 26. Did you testify as an expert in the case of the American Bell Telephone Company *et al.* *v.* Albert Spencer *et al.*, in the**

United States Circuit Court within the District of Massachusetts, wherein a decision has been rendered for the complainants; and were you familiar with the telephonic apparatus therein complained of, and held by the Court to infringe upon the Bell patents aforesaid; if so, what was the character of the transmitting instrument to which the decision in that case applied?

Ans. I did testify as an expert for the complainants in the Spencer case referred to, and became familiar with the telephonic apparatus complained of therein. The transmitter of that apparatus was an articulating microphone, which operated in the manner and according to the method I have described in my last preceding answer.

Int. 27. Did you testify as an expert in the case of the American Bell Telephone Company *v.* Amos E. Dolbear *et al.*, in the United States Circuit Court within the District of Massachusetts, wherein a decision has also been rendered for the complainants; and were you familiar with the telephonic apparatus therein complained of, and held by the Court to infringe upon the Bell patent No. 174,465; if so, what was the character of the transmitting instrument belonging to the apparatus to which the decision in that case applied?

Ans. I testified in the case referred to, and became familiar with the apparatus in that case. The transmitter was an articulating microphone, and it operated in the manner which I have already described.

Int. 28. Did you testify as an expert in the case of American Bell Telephone Company *et al. v.* the People's Telephone Company *et al.*, in the United States Circuit Court, within the Southern District of New York, and in the case of same complainants against the Molecular Telephone Company *et al.* in the same Court, wherein decisions have also been rendered for the complainants, and were you familiar with the telephonic apparatus therein complained of, and held by the Court to infringe upon the aforesaid patents to Bell? If so, what was the character of the transmitting instrument to which the decisions in those cases applied?

Ans. I testified as an expert in the cases referred to, and was familiar with the apparatus in those cases. The transmitting instru-

ments were articulating microphones, and operated in the manner which I have described.

Int. 29. You have said that the defendants' transmitter produces electrical undulations by utilizing the property of variation in electrical resistance with variation in pressure, possessed by various substances. Please compare the construction and mode of operation of the defendants' transmitter with the construction and mode of operation of the articulating microphone which you have explained, and point out their substantial likenesses and differences.

Ans. The specific mechanical details of the Exhibit Defendants' Transmitter in this case are somewhat different from those of the microphone transmitters described and those complained of in some of the other cases, but those differences in no way affect the fundamental likeness which exists between them all in respect to their essential mode of operation as electric speaking telephones. Each and all of them contain a diaphragm supported at the edges and capable of being vibrated by the sonorous vibrations in the air excited by uttering any word against the transmitter. One piece of material, called an electrode, is fastened rigidly to that diaphragm, or so connected with it that it partakes of its motion. The other electrode, which I call an anvil electrode, is so arranged that it can be moved by the vibratory motions of the diaphragm, but takes its motion entirely from the pressure against it of the first-mentioned electrode which is fastened to the diaphragm; and in all cases it is the effort of the vibrating diaphragm to move the second, or anvil electrode, which produces the variations in the contact pressure between them, giving rise to corresponding variations in the electrical resistance at the place of contact, and thus producing in the current passing through that contact, electrical undulations similar in form to the air vibrations which impress their motion upon the diaphragm. In all the cases, one or both of these electrodes are of carbon, a substance which is found peculiarly advantageous for the purpose of producing, by means of variations of contact pressure, corresponding variations of electrical resistance, and at the same time preventing breaks of the current, or those disturbances which are connected with, or immediately precede breaks. These features are common to the apparatus of the McDonough Company and to the

apparatus of Spencer, of Dolbear, of the Drawbaugh Company and of the Molecular Company. The microphone of the defendants' transmitter in this case is essentially the same, even in its details, as the microphone of the Molecular Company passed upon by Judge Wallace in the suit by the American Bell Telephone Company against the Molecular Company during the present year. It consists of a series of rods of carbon, the two ends of which are supported in sockets in blocks of carbon, which in turn are mounted upon the under surface of a nearly horizontal or slightly inclined diaphragm of wood, or, in the case of the Molecular Company, of cork. The blocks fastened to the diaphragm move with it; the rods of carbon resting on the blocks take their motions from them, and this varies the pressure at the point of contact in the way and to the effect already described. The Molecular transmitter and the transmitter of the defendants in this case are both essentially, and almost in details of form, the Hughes microphone as described in papers by Hughes and by Preece in 1878. They differ from those shown in the drawings of those publications chiefly in the fact that instead of using one rod and one or two contacts, as shown in the sketches of Prof. Hughes's instrument, they use a number of rods, each, however, mounted in substantially the same way as those made by Hughes. This, however, was a variation pointed out by Hughes himself in the articles in question. There he says that he finds it desirable to employ a number of contacts, and says that in various experiments he has used four contacts, six contacts, eight contacts, and ten contacts, and that the number of surfaces may be varied in accordance with the range and power of the vibrations.

The connections are so made in the defendants' transmitter that the current passes through a considerable number of these contacts at once, and thus, although it would be, in my judgment, an injury that any one of those contact pieces should break contact and interrupt such part of the current as passes through it, the injury would be less in their form of instrument than would follow if the whole current passed through one contact and should there be entirely interrupted.

Int. 30. Please compare Exhibit Defendants' Receiver with the receiving member L of the apparatus specifically described in the

patent to Bell, No. 174,465, and shown in Fig. 7 of the drawings thereof; and state what differences in construction you find, and how such differences affect, if at all, the substantial likeness of the two instruments in respect to their function and mode of operation, and the work they do in the transmission of sounds.

Ans. The Exhibit Defendants' Receiver is what is known as a magneto-telephone, and is merely a modification of the specific form of receiver shown in Fig. 7 of the patent of Bell, No. 174,465. The membrane diaphragm of the first Bell patent is replaced in the defendants' instrument by a diaphragm of zinc, or some similar metal. The discovery that a metal diaphragm, stiff enough to maintain itself without artificial straining, could be used in the speaking telephone, was announced in Mr. Bell's second patent, and I believe it to be his invention. Like the instrument Fig. 7 of the first Bell patent, the defendants' receiver has a soft iron armature attached to it. The support of this armature is not materially different from that in the first Bell patent. In the first Bell patent it is supported by the combined action of a hinged joint near the rim of the diaphragm and the elasticity and strength of the diaphragm itself. In the defendants' receiver it is supported by the elasticity and strength of a sheet of metal which is clamped at the edge of the frame which supports the rim of the diaphragm. At first sight, one would think that the freedom of action in the defendants' transmitter was even less than that possessed by the instrument of the first Bell patent; but in fact, as shown by Mr. Bell's second patent, the metal diaphragm itself is so elastic that for the purposes of the speaking telephone it gives all the required freedom.

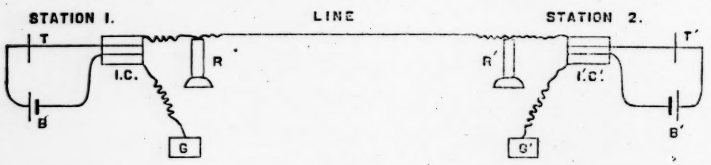
Their receiver contains an electro-magnet placed in front of a diaphragm and attached armature, while the coils of that electro-magnet are connected with a line wire leading to the transmitting station. This is true both of the instrument Fig. 7 of the patent, and of the defendants' instrument. It is the action of these on each other which makes the instrument operate.

In the instrument of the patent a battery is employed to magnetize the cores of the electro-magnet inside the coils. In the defendants' instrument the magnetism of those cores is obtained by permanently magnetizing the steel bar of which they are made. That is an im-

provement in detail described and introduced by Mr. Bell's second patent, but it does not change the nature of the apparatus as a whole, nor the nature of the operation performed by the receiver, nor the nature of the operation performed by the magnet itself as a subordinate part of the receiver. In each of them electrical undulations, similar in form to the sonorous vibrations, and caused by the action of the voice on the transmitter, passing over the line wire and through the coils of the receiving instrument, vary the attractive force of its electro-magnet, and thus influence the diaphragm armature of the receiver to copy the motion of the diaphragm of the transmitter. A similar sound to that uttered into the transmitter is then heard to proceed from the receiver.

Int. 31. Will you state more particularly the manner in which the defendants' transmitter and receiver are connected up in use, and the way in which the parts operate in the transmission of speech; and state in that answer the function of the induction coil contained in the same box with the transmitter?

Ans. The nature of the operation of defendants' transmitter and receiver when in use may be more clearly understood by a consideration of the following diagram, which shows the ordinary manner of connecting up such an apparatus.



I will describe what takes place when such an apparatus so connected up is spoken to. Suppose the variable contact transmitter T, or microphone transmitter, to be connected in a local circuit called the primary circuit, which includes the battery B and the primary helix of the induction coil I C. When the diaphragm of the said transmitter is spoken to, it takes up from the air vibratory motions of the same character as those performed by the air waves due to the speaker's voice. While performing this vibration the carbon blocks which are rigidly connected to the diaphragm press more or less strongly against the ends of the carbon cylinders carried

by these blocks, and tend to impart their own motion to the cylinders; but owing to the inertia of the carbon cylinders, there are developed at the points of contact of the cylinders and blocks, varying pressures corresponding to these vibratory motions of the diaphragm, and, as the electrical resistance of the circuit which passes through those points of contact varies with the pressure, it follows that the currents in the primary circuit are varied in accordance with the motions of the diaphragm, and thus these currents themselves are thrown into undulations which are similar in form to the sound waves produced by the speaker's voice and falling upon the diaphragm. The apparatus is so arranged, moreover, upon principles which are well known among constructors of telephones, and have long been in practical use, that the sound waves due to the ordinary tones of the voice, as they fall upon the diaphragm of the instrument, will not throw it into vibrations violent enough to cause the electrodes to part contact and interrupt the electrical current. The particular modifications adopted by the defendants are for the purpose, among other things, of preventing breaks. As these electrical undulations pass through the primary helix of the induction coil, they produce in the secondary helix and connected wires electrical undulations similar in form to those in the primary circuit; and these, passing through the coils of the two receivers, R at the speaking station and R′ at the receiving station, throw the diaphragm of each into vibration in the manner already described. The sounds in R at the speaking station are generally not listened to, but the listener at R′ at the listening station, — station 2, — placing his ear to the receiver, becomes sensible of sonorous vibrations of sounds which are the same in character, and recognizably the same in articulation, as those uttered into the transmitter. Now this operation which I have described is precisely the operation which I have already stated is performed by the apparatus shown in Fig. 7 of Mr. Bell's first patent; and the method by which the air waves at the speaking end produce like air waves at the receiving end consists in causing and utilizing electrical undulations similar in form to the sound waves.

In the case of the defendants' apparatus, it is because of the similarity between the electrical undulations and the sound waves

that the sound is so perfectly transmitted, and that speech is recognized and understood. So far as there is any difference between the form of the sound waves and the form of the electrical undulations, the speech loses its perfection; but, in the ordinary operation of that instrument, the similarity is amply sufficient for all practical and useful purposes.

It is customary, in the practical use of microphone transmitters, to employ an electrical apparatus known as an induction coil, in order to overcome more effectively the resistance of the circuit. An induction coil, as so used, consists of two entirely separate coils of wire, having a common axial core of soft iron. One of these coils is wound upon the outside of the other. The inner coil is composed of a small number of turns of rather coarse wire, and is called the primary coil. The outer coil is composed of a large number of turns of fine wire, and is called the secondary coil. The operation of the induction coil is such that, whenever a current of electricity of varying strength is caused to pass through the primary coil, if the ends of the secondary coil are connected with each other (either directly or indirectly, by means of a circuit which may contain a receiving telephone), a current possessing similar variations will flow through the secondary circuit. But in accordance with well-known electrical principles, the current thus generated in the secondary coil will have a far greater power of overcoming resistance than is possessed by the original current in the primary coil. The induction coil thus acts as a sort of electrical lever. In the use of the induction coil with a microphone transmitter, the transmitter with the battery is placed in circuit with the primary coil of the induction coil. The secondary coil is placed in circuit with the line wire and the receiving instrument. Such an induction coil is universally used in the Blake transmitter when employed for commercial purposes, and was present in the transmitter of the defendants in the Spencer case and in the Dolbear case, and in the case against The People's Telephone Company. I find such an induction coil in the Exhibit Defendants' Transmitter.

Int. 32. You have in the last preceding answer mentioned the function of the battery shown in Fig. 7 of the patent to Bell, No. 174,465, in respect to the magnetization of the electro-magnet;

will you explain the operation and effect of the transmitting member A of the telephone instrument shown in that Fig. 7, upon the battery current, when such transmitting member is actuated by the vibrations of the air accompanying vocal or other sounds?

Ans. I have already explained the manner in which currents of electricity are produced in a circuit, when an armature like that at *c*, Fig. 7, vibrates to and fro in front of the pole of an electro-magnet. The motion of the armature is capable of producing a current, solely in virtue of the electro-motive force which its motion sets up in the circuit. The magnitude of this electro-motive force depends upon the velocity with which the armature is moving at the moment under consideration, and the direction in which this electro-motive force acts is determined by the direction of motion of the armature, being reversed when the armature changes the direction of its motion. Therefore if there is a battery in the circuit, the total current in the circuit at any given instant will be that due to the algebraic sum of the electro-motive force of the battery, which we may assume to be constant, and the electro-motive force produced in the circuit at the instant considered, by the motion of the armature, which last electro-motive force, as I have said, is dependent upon the velocity of the armature at the instant considered. When the electro-motive force due to the motion of the armature coincides in direction with the electro-motive force due to the battery, this last electro-motive force is evidently strengthened by the addition; and hence the total current flowing in the circuit is correspondingly increased; that is, the battery current is strengthened by an amount equal to that of the current which the vibrating armature alone would produce in the circuit if the battery were removed and the cores of the electro-magnet magnetized in some other manner. If the electro-motive force due to the motion of the armature is opposite in direction to that due to the battery, the current will be weakened. Hence, as the armature moves to and fro, every change in the direction or velocity of its motion will produce a corresponding change in the strength of the current flowing in the circuit.

Int. 33. Will you refer to the second Bell patent, No. 186,787, which has been produced in evidence, and describe briefly so much

of the apparatus therein described as is referred to in the third, fifth, sixth, seventh and eighth claims, pointing out the functions or results which are attributed to the parts of the apparatus referred to in those claims?

Ans. Claim 3 is as follows: —

"3. The combination with an electro-magnet, of a plate of iron or steel, or other material capable of inductive action, which can be thrown into vibration by the movement of surrounding air or by the attraction of a magnet."

By this, I understand an electro-magnet combined with a plate of iron, steel or other material capable of inductive action.

To satisfy the conditions of this claim, the plate must be of such material, size, thickness and elasticity, and must be so mounted and arranged with reference to the magnet, that on the one hand the delicate air vibrations characterizing articulate speech may be able to impart their vibration to it without substantial alteration in character; while on the other hand, it is capable of being set into vibration through the action upon it of the minute changes imparted to the magnet by the variations in the current passing through the coil surrounding it, when those variations are of the delicate character which are employed in the transmission of speech in the speaking telephone.

Claim 5 is as follows: —

"5. The formation, in an electric telephone such as herein shown and described, of a magnet with a coil upon the end or ends of the magnet nearest the plate."

This claim relates to the special form of magnet suited for use in an electric telephone, the coil being placed about the end or ends of the magnet nearest the plate. The object of thus placing the coil is to render the magnet quicker in its working; that is, more ready to respond with the requisite rapidity to the variations in the strength of the current passing through the coil. A magnet with the coil thus placed responds more quickly by changes in its strength to slight changes in the strength of the current, and hence it is better adapted for use in the speaking telephone than a magnet in which

the coil surrounds the whole length of the magnet, and which consequently acts more slowly.

Claim 6 is as follows: —

"6. The combination, with an electric telephone such as described, of a sounding-box, substantially as herein shown and set forth."

In this claim is mentioned the sounding box, which is combined with the telephone. This sounding box has an important influence in screening the plate of the instrument from the effect of extraneous sounds. The thin air space in front of the plate also exercises an important influence.

Claim 7 is as follows: —

"7. In combination with an electric telephone, as herein described, the employment of a speaking or hearing tube for conveying sounds to or from the telephone, substantially as set forth."

The speaking or hearing tube mentioned in this claim serves to concentrate the sounds produced by the voice upon the diaphragm when used as a transmitter, or to convey to the ear the sounds produced by the diaphragm when used as a receiver.

Claim 8 is as follows: —

"8. In a system of electric telephony, the combination of a permanent magnet with a plate of iron or steel, or other material capable of inductive action, with coils upon the end or ends of said magnet nearest the plate, substantially as set forth."

In this claim I find mentioned the combination of a permanent magnet with coils upon its end or ends, as described, with a plate of iron, or other material capable of inductive action. The use of the plate of iron, in connection with the magnet, as described, in a system of electric telephony, furnishes a most excellent method of causing the electrical and magnetic variations of the apparatus to produce corresponding vibrations in the air.

Int. 34. Referring to the defendants' instruments which have been introduced in evidence, will you compare them with the apparatus described in the patent last referred to, and state how far, if at all, you find them to embrace the features or combinations described in that patent, and referred to in the claims above specified?

Ans. Among the most important improvements introduced by Mr. Bell's second patent is the substitution of a diaphragm of elastic metal, not artificially strained, in place of the stretched membrane. Such a metal diaphragm is a great improvement over the membrane. Its vibrations are more true and it is less affected by the ordinary accidents and exposure to which the instrument for commercial use is liable. Its tension always remains substantially the same. It needs no special care to keep it dry. To make this improvement in the telephone involved the discovery that a plate of metal, thick enough to sustain itself without artificial straining, could be made to truly and effectively vibrate under the very delicate forces which are available either at the transmitting member or at the receiving member of the speaking telephone; that is, the air vibrations due to the voice or the magnetic variations which arise in the transmission of speech. The state of knowledge at the time when Mr. Bell took this patent, except for what Mr. Bell himself had during the preceding summer made known, was such that one could not have asserted that the substitution could be made.

The claims of Mr. Bell's second patent which refer to this feature — I mean the third and eighth claims — refer in terms to a diaphragm of iron or steel or other inductive metal. The defendants use a compound structure consisting of a plate of zinc, which is not ranked as inductive metal, to the central portion of which they attach a soft-iron armature, which is inductive. That structure as a whole is so essentially the same as the plate of Mr. Bell's patent that it needed no invention to construct and use it in the telephone after one was possessed of the knowledge conveyed by Mr. Bell's first and second patents. The use of this composite structure of the defendants substantially obtains the advantages which are obtained by substituting the metal plate of Mr. Bell's second patent for the membrane and attached armature of the first patent; and the possibility of using this composite structure of the defendants' instrument depends upon the knowledge of the discovery promulgated by Mr. Bell, that a metal plate capable of sustaining itself without artificial straining could be effectively operated by the feeble forces which act upon it in the speaking telephone. I am very certain, therefore, that the defendants' receiver, in respect to the

character of the structure of its diaphragm, embodies and avails itself of the invention and improvement in that respect set forth in Mr. Bell's second patent. Whether the language employed in the patent does or does not make Mr. Bell's claim essentially narrower than his invention, is, I suppose, a question of law upon which I need not express an opinion.

Another important invention disclosed in Mr. Bell's second patent consists of the substitution of a bar of steel, permanently magnetized, for the soft iron electro-magnet magnetized by a battery current, shown in Fig. 7 of the first patent. The advantage is chiefly in economy and convenience, but it is one which, according to the statements made as to the extent of the use of telephones in this country, saves the use of probably one hundred and fifty thousand batteries. The defendants' receiver uses this improvement; and to use it in the way they do needed no information beyond that disclosed by the second patent. Whether here, again, Mr. Bell has so drawn his patent as to make his claims essentially narrower than his invention, is a question upon which I am not called to express an opinion.

Another important improvement disclosed by Mr. Bell's second patent consisted in the form of the air spaces and casings, which he has substituted for the two cones in Fig. 7 of the first patent. In the instrument of the second patent, No. 186,787, the principal part of the case encloses the rear of the diaphragm and the magnet and connected parts, and thus protects them and the ear of the listener exposed to that diaphragm from extraneous sounds falling on the back side of the diaphragm. This is an improvement of considerable practical importance. I have made a number of experiments which demonstrated the importance of it. It is a feature which is universally used in all commercial instruments. The instrument of the second patent also has its casings so constructed as to provide in front of the diaphragm a thin circular air space, with a circular opening at its centre to enable sonorous air vibrations to pass from the diaphragm to the ear of the listener, or to the diaphragm from the mouth of the speaker. This form of air space is a marked improvement over the form of the first patent, and has been universally used in all, or nearly all, telephones since. These features

are particularly referred to in the sixth and seventh claims of Mr. Bell's patent No. 186,787, and are found in the defendants' instruments. The instrument of the patent is shown as a box adapted to rest upon the table, and with such an instrument a tube of some length is a convenience. When the apparatus has taken the ordinary commercial form of the hand instrument readily applied to the ear, that tube becomes useless as a long tube; but the essential feature of the communication between the diaphragm and the operator, to wit, a thin air space of substantially the size of the diaphragm, with a small circular opening at its centre, is the most important part of the arrangement, and that is preserved in the defendants' instrument. The form of the rear casing and sound box and air space of the defendants' instrument, as I have described it, is the same as that of the various receivers used by the defendants in the different suits referred to in this deposition, which have been adjudged by the Courts.

I have spoken of the defendants' magneto instrument chiefly as if it were simply a receiver; but it is also capable of use as a transmitter. When the connections are made as I have shown in a previous answer, and as they are ordinarily made in a speaking telephone apparatus, there is one of these magneto instruments at each end of the line, and an operator there who desires to use it if his microphone be out of order, or for any other reason, has only to speak into it and the listener at the other end listening at his magneto instrument in the ordinary way will be so connected with him that conversation can be carried on. When the defendants furnish to any one the apparatus arranged and connected in the usual way, as I have described, they furnish him besides the microphone apparatus an apparatus consisting of a magneto transmitter and a magneto receiver, equipped and ready for use if he chooses to use them.

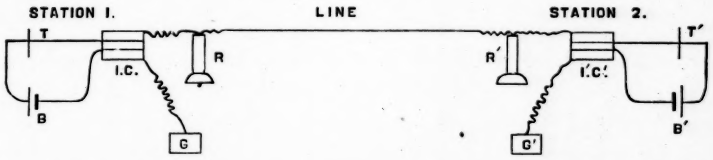
Int. 35. I find in the second Bell patent a statement that the same instrument is used both as transmitter and receiver, and I understand that the electrical and magnetic portions of the apparatus described in Bell's first patent are the same both in the transmitter and receiver, the instruments differing merely in the forms of the cones, one of which is especially adapted to enclose the mouth, while the other is shaped so as to enter or be applied to the ear; will

you state whether the magneto telephone Exhibit Defendants' Receiver is, when properly connected in line with another instrument of the same kind, capable of being used as a transmitter as well as a receiver?

Ans. It is capable of being used both as transmitter and receiver under the circumstances mentioned.

Int. 36. Will you describe the character of the circuits and connections indicated by the structure of the defendants' two instruments, and usual with a speaking telephone apparatus which includes a battery transmitter, and then state whether the magneto instruments, as arranged at the two ends of the line, will be so connected in circuit with each other that, without any change, speech uttered into one will be heard at the other?

Ans. I make the following drawing to illustrate my meaning: —



In the figure, I C and I′ C′ are two induction coils; B and B′ are voltaic batteries, and T and T′ transmitters in the primary circuits of the coils. R and R′ are magneto telephones placed in a line connected with one terminal of the secondary wire of each induction coil. G and G′ are earth plates, with connecting wires running to the other terminals of the secondary wires of the induction coils. G and G′ are buried in the earth, so that the secondary circuit is completed through the earth, and includes the secondary helices of the two induction coils, and the two magneto telephones R and R′. Speech actuating either T or T′ is reproduced in the receivers R and R′. Also, if either R or R′ be spoken into and used as a transmitter, since R and R′ are joined in complete circuit by means of the line wire, the secondary wires of the coils, and the earth, speech will be reproduced in the other receiver, as when the apparatus shown in Fig. 7 of the first Bell patent, or Figs. 4 and 6 of the second Bell patent, is used.

This is the ordinary arrangement, and, as indicated by the con-

struction of the defendants' transmitter, is the arrangement intended to be used by them. Indeed, it is not uncommon on ordinary telephone lines, as thus arranged, to use one of the magneto instruments as a transmitter, when for any cause the microphone transmitter, the battery, or any portion of the primary circuit is out of order.

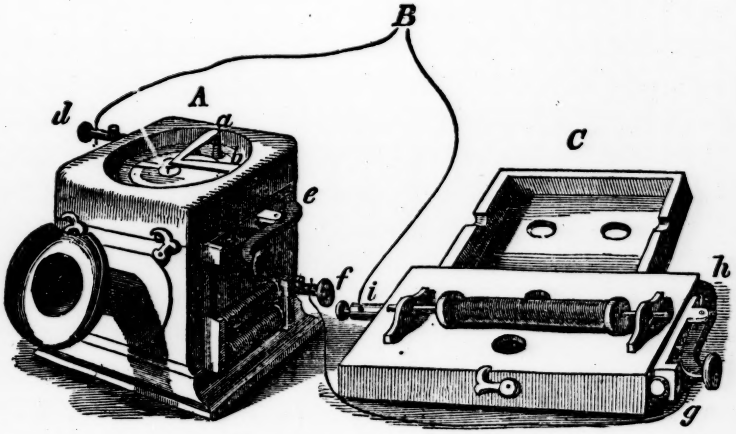
Int. 37. I understand from your previous testimony, that in a speaking telephone apparatus consisting of transmitters, receivers, batteries and other adjuncts, as shown in the above diagram, the articulate speech uttered into any transmitter is heard at the receiver as the same articulate speech in consequence of the electrical undulations similar in form to the sound waves, and that those electrical undulations are caused by the utterances of the speaker, which said sound waves are due to or accompany. I wish you would now state, by reference to said diagram, in what part of the whole apparatus, including in that phrase the various circuits, those electrical undulations exist, and in what part they must exist and be operative, in order that speech may be transmitted so as to be intelligible to the listener.

Ans. If a person speaks into one of the transmitters, as, for example, T at station 1, the current produced in the primary circuit by the battery B is thrown into the described electrical undulations by the action of the voice upon the transmitter. These undulations occur throughout the whole primary circuit of the induction coil I C. Similar electrical undulations are produced in the secondary of I C, and in the whole circuit of which it forms a part, including the magneto-telephones R and R′, and the secondary wire of the induction coil I′ C′. Similar undulations are also produced in the primary of the induction coil I′ C′; but in this circuit they have no importance. These electrical undulations are produced in the primary circuit by the action of the voice upon the transmitter. It follows, from the relation of the primary and secondary helices of the induction coil, that undulations similar in form are produced in the secondary wire, the line, and the receiving instruments placed in the circuit. It is because of the presence of these electrical undulations in the secondary circuit, and of their similarity to the undulations produced by the voice in the primary circuit, that words spoken into the transmitter are reproduced by the receiver.

Int. 38. That the Court may more clearly understand the nature of the novelty introduced by Mr. Bell, will you please read from Reis's advertising circular of Aug. 9, 1863, the description he there gives of the operation of his instrument:—

Ans. I find in Reis's circular the following statements:—

[REIS'S DESCRIPTIVE CIRCULAR.]



"The apparatus consists of two parts, as may be seen in the wood-cuts above, the telephone proper A, and the reproducing apparatus C. These two parts are to be placed at such a distance from each other that singing or the sound of a musical instrument can be heard in no other manner, except through the apparatus from one station to another.

. . . . . .

"If now sufficiently strong tones are produced before the mouth-pieces, their vibrations will put in motion the membrane and the angular little hammer [winkelförmige Hämmerchen], which lies on it; for every full vibration the circuit is once opened and again closed [einmal geöfnet und wieder geschlossen], and thereby are produced at station C in the core of the coil, just the same number of vibrations [ebensoviele Schwingungen hervor-gebracht] which are there perceived as tones or as combinations of tones [accords]."

Int. 39. Will an instrument so operating transmit articulate speech?

Ans. It will not.

Int. 40. Prof. Hughes wrote two articles in 1878 concerning an apparatus which he produced and called a microphone; the second one of those was read before the Physical Society, at London, June 8, 1878, and is entitled "On the Physical Action of the Microphone." In it I find the following: —

"The problem which the microphone solves is this: To introduce into an electrical circuit an electrical resistance, which resistance shall vary in exact accord with sonorous vibrations so as to produce an undulatory current of electricity from a constant source, whose wave-length, height and form shall be an exact representation of the sonorous waves. In the microphone we have an electric conductin material susceptible of being influenced by sonorous vibrations, and thus we have the first step of the problem.

"The second step is one of the highest importance. It is essential that the electrical current flowing be thrown into waves of determinate form, by the sole action of the sonorous vibrations. I resolved this by the discovery that when an electric conducting matter in a divided state, either in the form of powder, filings, or surfaces, is put under a certain slight pressure, far less than that which would produce cohesion, and more than would allow it to be separated by sonorous vibrations, the following state of things occurs. The molecules at these surfaces being in a comparatively free state, although electrically joined, do of themselves so arrange their form, their number in contact, or their pressure (by increased size or orbit of revolution), that the increase and decrease of electrical resistance of the circuit is altered in a very remarkable manner, so much so as to be almost fabulous.

"The problem being solved, it is only necessary to observe certain general considerations to produce an endless variety of microphones, each having a special range of resistance.

"The tramp of a fly or the cry of an insect requires little range, but great sensitiveness; and two surfaces, therefore, of chosen materials under a very slight pressure, such as the mere weight of a small superposed conducter, suffice; but it would be unsuitable for a man's voice, as the vibrations would be too powerful, and would, in fact, go so far beyond the legitimate range, that interruptions of contact amounting to the well-known 'make and break' would be produced.

"A man's voice requires four surfaces of pine charcoal, as is described in my paper to the Royal Society, six of willow charcoal, eight of boxwood, and ten of gas carbon. The effects however, are far superior with the four of pine, than with either the ten of gas carbon or any other material, as yet used. It should be noted that pine wood is the best resonant material we possess; and it preserves

its structure and quality, when converted into the peculiar charcoal I have discovered and described.

"It is not only necessary to vary the number of surfaces and materials, in accordance with the range and power of the vibrations, but these surfaces and materials must be put under more or less pressure, in accordance with the force of the sonorous vibrations. Thus for a man's voice, the surfaces must be under a far greater pressure than for the movements of insects. Still, the range of useful effect is very great, as the boxes which I have specially arranged for a man's voice are still sensitive to the tick of a watch.

"In all cases it should be so arranged that a perfect undulatory current is obtained from the sonorous vibrations of a certain range. Thus, when speaking to a microphone transmitter of human speech, a galvanometer should be placed in the circuit, and while speaking, the needle should not be deflected as the waves of + and — electricity are equal, and are too rapid to disturb the needle, which can only indicate a general weakening or strengthening of the current. If the pressure on the materials is not sufficient, we shall have a constant succession of interruptions of contact, and the galvanometer needle will indicate the fact. If the pressure on the materials is gradually increased, the tones will be loud but wanting in distinctness, the galvanometer indicating interruptions; as the pressure is still increased, the tone becomes clearer, and the galvanometer will be stationary when a maximum of loudness and clearness is attained. If the pressure be further increased, the sounds become weaker, though very clear; and as the pressure is still further augmented, the sounds die out (as if the speaker were talking and walking away at the same time), until a point is arrived at where there is complete silence.

"When the microphone is fixed to a resonant board, the lower contact should be fixed to the board so that the sonorous vibrations act directly on it. The upper contact where the pressure is applied should be as free as possible from the influence of the vibrations, except those directly transmitted to it by the surfaces underneath; it (the upper surface) should have its inertia supplemented by that of a balance weight. This inertia I find necessary, to keep the contact unbroken by powerful vibrations. No spring can supply the required inertia; but an adjustable spring may be used to insure that the comparatively heavy lever shall duly press on the contacts."

I will ask you whether there is, with our knowledge of to-day, any practical difficulty in constructing apparatus which, when spoken to with an ordinary tone of voice, will perform the operation there described, and, by reason thereof, will cause articulate speech to be heard and understood by one listening at a connected telephone

receiver of the kind in commercial use to-day and at the time when that article was written?

Ans. There is not.

Int. 41. In that article Prof. Hughes mentions carbon as a desirable material for the electrode, and referring to the mechanical structure of the instrument, says: —

"When the microphone is fixed to a resonant board, the lower contact should be fixed to the board so that the sonorous vibrations act directly on it. The upper contact, where the pressure is applied, should be as free as possible from the influence of the vibrations, except those directly transmitted to it by the surfaces underneath; it (the upper surface) should have its inertia supplemented by that of a balance weight. This inertia I find necessary, to keep the contact unbroken by powerful vibrations. No spring can supply the required inertia; but an adjustable spring may be used to insure that the comparatively heavy lever shall duly press on the contacts."

Will you state whether those physical features of the instrument are or are not adapted to make it perform the described operation with the described result?

Ans. They are adapted to do this.

Int. 42. Do you find physical features of that described character in the transmitter of the defendants' apparatus?

Ans. I do.

[*Complainants put in evidence said two articles, marked "Hughes, May 9, '78, Microphone Article," and "Hughes, June 8, '78, Microphone Article." Also a publication marked "Exhibit Preece Lecture of May 23, 1878, published in 1878," in Journal of Society of Telegraph Engineers, Vol. VII., p. 270, and an article "Thomson and Houston Microphone Relay," published in the Telegraphic Journal and Electrical Review, Aug. 15, 1878.*]

Int. 43. You have stated that speech is transmitted electrically by causing and by utilizing electrical undulations similar in form to the air vibrations of the sound to be transmitted; do you think that any apparatus which has ever been constructed will make those undulations to be copies of the sonorous undulations with theoretical and mathematical accuracy and perfection?

Ans. I do not know of any apparatus which would do this with absolute mathematical accuracy; but either the magneto transmit-

ter or the microphone transmitter will do this with sufficient precision to enable them to be successfully and practically employed in the art of transmitting speech.

Int. 44. When a telephone apparatus is brought to you and set in operation by the voice, can you tell whether the current changes in it are substantially the current interruptions mentioned in the Reis article, which have been referred to, or substantially the electrical undulations similar in form to the sonorous vibrations mentioned in the Bell patent, No. 174,465, and in the Hughes article, an extract from which was given in Int. 40?

Ans. I can readily tell in which one of these two ways the current changes are produced.

Int. 45. If the preceding question can be answered by experimental proof or tests, will you please state the nature of the tests adapted to answer it?

Ans. No instrument is so well adapted to determine the nature of such rapid current variations as are produced either by the Reis transmitter, the magneto transmitter, or the microphone, as a magneto telephone receiver of the ordinary butter-stamp pattern. I think that the nature of the tests by which one would ascertain the character of the electrical variations produced by different forms of transmitter will be more clearly understood if I analyze at some slight length the nature of the test which a magneto receiver furnishes, and the nature of the evidence which satisfies me of the substantial identity existing between the currents produced by a magneto transmitter and those produced by a microphone transmitter, as, for example, the transmitter employed by the defendants.

In any experimental study of electrical changes, there are two ways by which we may determine the nature of those changes: —

1. We may study the instrument producing those changes, and observe its construction and its mode of operation. We can thus ascertain what will be the effects which, according to existing knowledge, must result from this operation.

2. We may make use of some instrument which is adapted to detect the occurrence and enable us to determine the nature of such changes as we have reason to believe are produced.

Considering the application to the telephone of the second mode of proof which I have mentioned, we know that telephonic currents are characterized, 1st, by great rapidity in succession; 2d, by great feebleness; 3d, by peculiarities analogous to the form of an acoustic wave. We must therefore employ some testing instrument which will detect changes of this peculiar nature. The Bell magneto receiver is universally recognized as, among all instruments, the best suited to this purpose. The galvanometer and the electro-dynamometer will not suffice, since they are not adapted to exhibit to an observer these phenomena in their completeness, as they will neither of them take cognizance of the nature of the rapid changes in the strength of the current, which are employed in transmitting sound vibrations; whereas, what we wish to study and compare in two instruments is the nature of the changes in the strength of the current and not its absolute average strength.

Using such a magneto receiver to compare the current variations produced by an instrument like that shown in Fig. 7 of the Bell patent, No. 174,465, and such an instrument as the defendants' transmitter, we find that the sound heard by the ear at the receiver, when a given sound is produced at the transmitter, is substantially the same in its quality or articulate character in both cases. It follows that the air at the ear of the listener at the receiver in the two cases must vibrate in substantially the same manner, and, to produce the same articulate speech, must have the same character of vibration due to form. But the air is in both cases set in motion by the vibrations of the plate at the receiver; hence the plate must in both cases have the same form of vibration. If the same word is spoken into either transmitter, the same word is heard at the receiver; hence the character of the vibration of the plate must be the same in both cases. The vibrations of the plate are in their turn produced by variations in the strength of the magnet, so that there must be the same form or character in variations in the strength of the magnet in both cases. Again, these magnetic variations are due to variations in the strength of the current, and as the magnetic variations are the same in character with either transmitter, the current variations producing these cannot but be the same in their character or form. Not only do these general statements hold, but the well-

known mathematical laws connecting the different links in this chain of results are such that even a very slight change in one will cause a change in the others, which would necessarily be recognized. Hence, there cannot be any material difference between the character of the currents in two such instruments as I have compared.

On the other hand, if we place a magneto receiver in circuit with a circuit-breaking transmitter, like the Reis, we find that the sounds produced at the receiver are totally different in their quality from those which are produced when a microphone transmitter, such, for example, as the defendants' transmitter, is used; so that by tracing the several steps in the operation backward, we are forced to conclude that the current changes are entirely different with the Reis transmitter from what they are with the defendants' microphone transmitter.

We can also employ in this study the first method of proof which I mentioned; that is, determining those effects which, according to existing knowledge, should result from the operation of the transmitter. Let us consider the nature of the changes that would be produced upon known principles when a microphone like the defendants' transmitter is actuated by sound waves produced by the voice. In the first place, it is a known fact that the change of current which is brought about by such a change of pressure between the electrodes as the voice is capable of producing is recognizable not only with the telephone, but also with a delicate galvanometer. This has been proved by slowly and carefully varying the pressure between two electrodes put in circuit with a sensitive galvanometer and apparatus adapted for measuring slight and slow variations in resistance. It is also a well-ascertained fact that the change thus produced in a current corresponds to the change of pressure under such circumstances as exist in a microphone like the defendants' transmitter. This fact has been abundantly proved by repeated experiments.

The defendants' transmitter is mechanically arranged, so that one using it may obtain variations in pressure between the electrodes corresponding in character with the variations in the air waves produced by the voice. Hence, in accordance with well-known laws, if we consider the results which should follow when such a transmitter is actuated by the voice, we find that variations in the current

should be produced which will have the same character as those which on both mathematical and experimental grounds are known to exist with the form of telephone described by Mr. Bell and illustrated in Fig. 7 of his patent, No. 174,465.

Now when we place a suitable testing instrument, such as a magneto receiver, in circuit with the defendants' or other microphone transmitter, we observe precisely such consequences as should, according to our knowledge of the laws of nature, result from the mode of operation of the transmitter, and these consequences are the same as should, according to known laws, and actually do result from the operation of the magneto transmitter. Hence, both study based on the known laws of electricity and magnetism, and practical testing give the same results as to the nature of the current changes in the two cases. In such a comparison as this, I should, therefore, be forced to conclude that the nature of the current variations produced and utilized in the two cases are substantially identical. It is, of course, true that of any two instruments, one may approach more closely to perfection than the other as to clearness or loudness of articulation, but that the same articulation is heard in both cases shows that the mode of operation is the same.

Int. 46. Will you give us some idea of how valuable and sensitive a testing apparatus the ordinary magneto telephone receiver is, for the purpose of disclosing absolute interruptions or other similar disturbances in an electrical current, including the case of such interruptions in a uniform current and such interruptions in an articulating undulatory current?

Ans. The magneto receiving telephone has been universally recognized as an excessively delicate instrument for testing as to the existence and nature of extremely delicate changes of current. Kohlrausch has substituted a magneto receiver for a delicate galvanometer in a form of Wheatstone's bridge, used by him, in which alternating currents are employed. Hughes has employed it in his induction balance, and Spottiswoode in investigating the nature of the electrical discharge through a vacuum tube. I have used a magneto telephone myself, and studied its value as a detector of breaks and small current variations. I have found it capable of detecting an interruption or sudden variation in the strength of either a con-

stant battery current or such an articulating current as is produced by a telephone, when this interruption or variation did not last more than $\frac{1}{50000}$, or in some cases, if I recollect rightly, even $\frac{1}{70000}$ of a second.

Int. 47. Will you state how the certainty arrived at in the way you described compares with the certainty on which are based scientific researches in electricity, the construction and use of scientific and electrical apparatus, and on which are based the practical applications of electricity in the arts, and the construction of instruments of various kinds for commercial use.

Ans. The certainty thus reached is precisely that certainty which raises electrical research to the rank of a science. We are ignorant of the ultimate nature of electricity, as we are ignorant of the ultimate nature of gravitation or of matter, but the laws of its action are very perfectly known, and variations in its amount can be measured with wonderful precision. The laws of electrical currents are so well known that they are subject to mathematical calculation, and we are able to predict with great certainty what will take place under different circumstances. All of our electric measuring apparatus is based upon those mathematical formulæ which express the laws of electrical action. Whenever, either in the laboratory or in the arts, we construct a particular kind of instrument, we know that with it, under definite circumstances, definite and identical changes of current will follow. The certainty which we have as to the results of our measurements is a certainty which is abundantly sufficient to maintain science and support the arts.

Int. 48. Two or three years ago, in the Ghegan case, you presented a statement of some experiments you had made which bear upon the subject of your last answers. If you have collected in a convenient form a statement of those experiments or most of them, will you present it, and read it as part of your answer.

Ans. In the experiments in the Ghegan case, the point mainly in view was to ascertain whether the variations of pressure operating in the microphone transmitter are competent to produce electrical undulations similar in form to the sound waves, and sufficient to account for the transmission of speech. To ascertain this, measurements were made of the effects of excessively slight variations of

pressure between contact pieces of carbon and other materials, when produced gradually.

I also made use of a carbon transmitter, with its contact surfaces so arranged that under the action of the voice, the pressure between these was varied while the electrical contact could not possibly be broken. The electrodes of the transmitter were also arranged in such a way that they were pressed together by a force far too great on mechanical principles to allow of separation with the small forces applied. In some experiments the electrodes were clamped so that electrical continuity could not be interrupted. With all these forms of instrument I observed the results which I obtained with a magneto receiver interposed in the circuit. Comparing these results with what I obtained in defendants' transmitter and other microphones, I was convinced that the currents and the nature of the action causing them were essentially the same in all.

Proceeding further, I produced at the transmitter intermittences and other sudden disturbances of excessively minute duration, and under such conditions of arrangement of battery and circuits that they should produce the least possible effect. I caused these to be produced on a line over which speech was being transmitted. A peculiar characteristic disturbing sound occurred in the receiver whenever I introduced those disturbances, and long before they reached any such magnitude as the interruptions which Reis used in his battery circuit, speech was completely obliterated.

I found no such disturbing causes to arise when listening to the defendants' receiver, or any other receiver put in circuit with their transmitter, and became sure that such disturbing causes did not exist.

In studying the capacity of the magneto receiver as a testing instrument, I have found no kind of sudden disturbance, especially of the nature of a break, which did not reveal itself by a characteristic sound at the receiver interfering with, and if carried sufficiently far, destroying articulation; though long before articulation is destroyed, the disturbances are recognized as impairing articulation. I found no such disturbances with the instrument of the defendants.

The experiments to which I am referring have been collected and put into complete form, and I here produce a copy: —

Several years ago I made a long series of experiments with a view to determine whether a microphone actually breaks contact while transmitting articulation in the most approved manner. I will state the results which I reached by these experiments, and which are briefly as follows: —

When, by the sound of the voice, the two electrodes of a microphone are so moved with reference to each other as to vary the force with which one is pressed upon the other, without interrupting the electrical current, articulation by any well-constructed instrument can readily be transmitted with very great perfection; on the other hand, when the vibration becomes great, so that they part company sufficiently to interrupt the current, a perfectly marked and peculiar sound is heard in the receiver, which, if frequently repeated or long continued, absolutely interrupts articulation. If this occurs but seldom, or for an instant at a time, it disturbs articulation, but does not absolutely prevent the sounds from being recognized and the sentence from being understoood There seems, also, besides the clicks and disturbances which operators with the telephone are accustomed to speak of as "breaks," to be an intermediate sort of condition frequently known as "scratching" or "jarring," in which abnormal sounds, not quite so sharp as those caused by breaks, yet perfectly distinguishable from articulation, come in and disturb, and, if sufficiently violent and long continued, prevent articulation from being transmitted. These sounds are readily produced by scratching one carbon over another without separating them, or by very rapidly moving them apart, nearly but not quite to the point of interrupting the current; jarring or rubbing them together will produce these sounds; jarring the table or wall which supports the instrument will also produce them. They appear to be due to abnormal disturbances of the contact, which prevent the electrical variations from taking the form of true articulating undulations, and yet do not always disturb them sufficiently to cause the sounds to be unrecognizable. The ear seems to have the power, particularly when the attention is directed to this end, of perceiving articulate sounds in the midst of a great many disturbing noises; we always recognize this in talking in a crowded room, and the same faculty is quite noticeable when the ear is listening to a receiving telephone actuated by currents over a circuit on which the true articulating undulations have been produced, but are more or less deformed or disturbed by extraneous electrical causes, either in the nature of interruptions or of superposition of different sorts of currents or variations. This is always noticed in the telephone, in ordinary use, when there is a "cross" on the line, as it is called; that is, when currents come in

from another line from an accidental misconnection, or when there are those disturbances from leakage or induction which are very prevalent on city lines. It not unfrequently happens from accident, such as the crossing of two wires, that the listener at the telephone hears two people talking at once. The currents which then reach the receiving telephone, and the sounds which reach the listener's ear are not simply the electrical undulations due to the voice of the person he desires to listen to, but are considerably deformed by the speech of the other; and oftentimes by fixing the attention you can hear and understand the one person or the other, or sometimes both. It is certain, therefore, and is a matter of every-day experience, that for the recognition of an articulate sentence it is unnecessary that the sound heard by the listener should be *exactly* the same as that uttered by the speaker; it may be mingled with other noises which may be so slight as not to be important, or so serious as to be annoying; and which finally may become so great as to be destructive, either by practically changing the character of the sound or by deadening the ear to the more delicate changes which constitute articulation.

I am entirely certain that the defendants' transmitter and other microphones transmit speech by varying the current in substantial accordance with the actuating sound waves, and not by interrupting it; that every interruption of the current which any known instrument can produce, causes in the telephonic receivers in ordinary use, a distinct and characteristic sound which is quite different from articulation, and which does not aid articulation, but disturbs it. When sufficiently increased, this disturbance becomes so great that the listener ceases to understand speech. The slightest interruptions of the battery current, occurring with a frequency much less than that of the vibrations characterizing articulate speech, become not only noticeable as disturbances, but destructive of speech.

These interruptions produce two disturbing effects; considered merely as interruptions of the electrical path between the transmitter and receiver, they for the time being cut off connection between them; however short this may be, some characteristics are lost. When this interruption is for a small fraction of a second and is not too often repeated, familiar sounds, including words, are still recognizable by what is left, and in spite of (but not by reason of) the loss. But if the interruption occurs in a circuit in which a battery is placed (and a battery is always and necessarily placed in the circuit which includes the working contact of the defendants' transmitter), then instead of the slight variations of current due to the merely varying (but not interrupting) operation of the microphone, amounting to only a small percentage of the full force of the battery current, the whole force of the current will, by the breaks, be thrown off and on, and abnormally great variations will take place; of themselves they will produce in the receiver a sound abnormally

loud and distinctly recognizable as characteristic of a break, and entirely different from articulation. When the slightest effect of this kind is added to the microphonic effects, its disturbing character is at once perceived, and as it is increased the disturbance becomes so great as to drown the articulation.

By many experiments, some of which I will state, I have satisfied myself that it is practically impossible, by any known instrument, to produce an interruption of a battery current which the speaking telephone receiver will not recognize as a disturbance; that any such interruption, however slight, if at all frequent, destroys the utility for commercial use.

I constructed an apparatus in which I could produce, at the same time and by the same action of the voice on the same diaphragm, articulating undulations in one part of the apparatus, and makes and breaks in another, and then at pleasure connect the two in one circuit, so that the results of both should pass over the same circuit to the same receiver.

For this purpose I took a Blake transmitter with the electrodes arranged in the usual manner, one of them being of carbon and the other of platinum, as usual. Close alongside of these electrodes and connected to the same diaphragm, so as to be subject to precisely the same motions, I arranged another pair of electrodes, both of platinum, as follows: one of this auxiliary pair consisted of a platinum electrode precisely like that of the ordinary Blake, but in this instance soldered to the diaphragm. The other of this auxiliary pair of electrodes consisted of a platinum contact piece rigidly fastened to a stiff cast-iron lever, which could be adjusted towards and away from the first platinum electrode of the pair by means of an adjusting screw, so that I could give to the two platinum electrodes such adjustment as I desired, and could place them either in very delicate contact with the slightest touch which would permit a current to pass, or just out of contact at the smallest distance which would interrupt the current. I adjusted the carbon contact so as to give good articulation when the mouth of the speaker was brought quite close to the instrument and exerted with rather more force than usual. With this arrangement perfectly good articulation was transmitted with ease. I then arranged the platinum electrodes in excessively delicate contact with each other, by which I mean that I brought them up together with the slightest touch which would permit the current to pass, and with as little pressure as possible. My idea was that I could thus speak to the diaphragm in a loud voice, and cause the carbon contact to produce the articulating undulations without break of contact; while the platinum contact pieces which had been brought farther apart, though still in electrical contact, and with the back one rigidly held and unable to follow the motion of the diaphragm, would generally part company and interrupt the current with the slight motions of diaphragm, which would be insufficient to break the main contact

when its platinum and carbon electrodes were firmly pressed together. Testing them separately, I found that this could be done by carefully modulating the voice, using a very loud tone. Intelligible speech in this tone could be transmitted with the carbon contact, but not with the platinum contact.

I then connected them together in one circuit, talking to the diaphragm now in the same loud tone that I used when talking to each separately. It was manifest that the carbon or articulating contact would operate as before; that is, would produce articulating undulations, and that the platinum contact would act as it did before, to produce breaks of an extremely delicate and slight character. When talking in an ordinary voice several inches away from the instrument, I got articulation and intelligible sentences due to the action of the carbon contact, and I recognized that the sound was substantially the same as when the platinum was not connected with the circuit, the motions in this case being too slight to break the continuity of the platinum contact. As I increased the effect of the voice, by causing the speaker to approach closer to the instrument and speak louder, the vibrations were still too weak to break the carbon contact, as I found by experiment, but were strong enough to break the peculiarly arranged platinum contact. This fact was instantly noticed in the receiver by the abnormal and sharply disturbing noises which were now added to the articulation. They were totally distinct from articulate sounds, and were markedly noticeable as disturbances, hindering, and finally drowning out speech for all purposes of practical utility, though some words were still recognized.

When the voice was at its loudest, producing the most disturbing effect, I caused the speaker to gradually speak more gently. As his voice fell off in violence, the disturbing noises became less, then ceased entirely, and the pure articulation came as before. The vibrations of a tuning-fork and the sounds of singing, and the prolonged note of vowel sounds, were also tried with similar results. The experiment was repeated many times.

This experiment has a special value. In it the vibrations of the diaphragm produce (by the finely adjusted carbon contact) those electric variations which transmit speech in the ordinary microphonic action of a microphone suitably adjusted for practical use; upon this are superposed interruptions of the battery current produced by the strong vibrations of the same diaphragm acted upon by the same sound. Thus the breaks at the platinum contact coincide in time with the minimum of current due to the action of the speaking or carbon contact, and are of the same frequency as the vibrations of the electrodes, with perhaps some omissions. These breaks produce in the receiving telephone sounds of peculiar character which the ear readily and distinctly recognizes as disturbing and inarticulate noises; while, when by gentleness in the voice or

by suitable changes in the adjustment of the platinum contact they are excluded, the modulations, due to the non-breaking carbon contact, are manifest by the articulations which they produce.

These experiments, if I had made no others, would have satisfied me that the telephone receiver is the most delicate detecter known of any abnormal disturbance in the currents, — particularly breaks or anything in the character of breaks, — by the peculiar and special sounds due to the slightest electrical disturbance of this nature. This is a fact generally recognized by scientific men.

I caused to be constructed a microphone with the parts so arranged as to permit of easy observation of the contact pieces. I made both of them of hard carbons, rounded and smoothed, and mounted one electrode so as to be in loose contact with the other when at rest. With this, speech was transmitted with entire ease, using a natural tone of voice and speaking several inches away. I then caused the voice to come nearer, to increase in loudness, and caused to be made various prolonged sounds which were adapted to give unusually great vibration to the instrument. During this time I observed the carbons with a microscope, which, in the various experiments, magnified from thirty to fifty diameters. Placing in the microscope a finely ruled glass eye-piece micrometer, I selected some little spot or protuberance on the carbon near one of the lines, and watched it. When thrown into rapid vibration, the spot by a well-known effect appeared to widen out into a blur, the width of which denoted the range of the vibrations. Having carefully watched the width of this blur under the influence of the vibrations produced by the voice, I ascertained that the vibrations due to ordinary speech, which was quite loud and perfectly understood, were so slight that they could with difficulty be detected by the microscope. As the voice was so exerted as to produce more powerful vibrations, the blur widened out more and more. I then, by means of a fine screw, drew back one of the electrodes until it had passed from a good working adjustment to a point where a galvanometer in the circuit showed the current to be interrupted, stopping with the smallest motion which produced this effect. During this time I watched the motion of a spot on the carbon with the microscope, and by the lines observed the distance necessary to break the circuit. Comparing this with the greatest range of vibrational movement produced during the transmission of speech with good articulation, I found that the smallest motion which would interrupt the current was many times greater than the largest due to the articulating vibrations.

During these experiments, also, I or another observer listened at a receiving telephone of the ordinary hard rubber pattern, included in the circuit. Any break observable by the galvanometer gave the usual characteristic sound in the receiver, so that we were thus satisfied that it became a reliable test of that break. The larger ranges of vibration which more nearly approached the breaking distance,

but did not reach it, gave the abnormal sounds, generally known as "scratching," which precede a full break and which partially or wholly prevent the reception of speech. When by appropriate means the instrument was thrown into violent vibrations (an electromagnet being included in the circuit), sparks were frequently observed with the microscope. They were always accompanied by the well-known disturbing sound of a break. I repeated these experiments many times on different days, until I satisfied myself that the results could be relied on.

I also tried the same kind of microscopic experiments with such a microphone transmitter as was used by the defendant in the Ghegan case, known as the Hopkins transmitter. Directing the microscope upon the contact of the two carbons, the corruscations of sparks which took place under the effect of abnormally loud vibrations were very striking. In such case and with any variations that produced sparks, the characteristic sounds already referred to were heard, and if the sparks were at all numerous, articulation became lost. In speaking to the instrument in a natural tone, and when in its best adjustment for speech, conversation was carried on as usual, and no sparks whatever appeared. Under these circumstances, the range of vibration of the Hopkins microphone was rather less than in my experimental instrument, and was many times inside the breaking limit.

Mere observation of the contact points, with or without the microscope, does not always enable one to say surely whether they are in contact or not. There is a well-known optical difficulty due to irradiation. Having satisfied myself on this point, I employed electrical tests, such as the galvanometer, to determine the electrical contacts.

These tests with the microscope satisfied me that no motion sufficient to interrupt the current takes place in any microphone when transmitting speech with the perfection required for commercial use. They also satisfied me that no break occurred in the circuit without the peculiar characteristic sound which the ear recognizes as a disturbance, and which, as it becomes more frequent and extensive, destroys articulation.

This confirmed the conclusions from other forms of tests, that speech is, in all cases, transmitted, not by breaks, but, when they occur, in spite of them.

I am sure that it is absolutely impossible to break the circuit with an articulating microphone, or to closely approach breaking the circuit without the production of an abnormal or disturbing sound, which the ear perfectly recognizes as distinct from articulation, and which is very injurious to articulation; and that when this is sufficiently frequent or sufficiently violent it prevents the transmission of speech.

It is true of all microphones capable of delicate adjustment that

conversation carried on several feet away from it may be transmitted, while the ordinary distance in practical use is from three inches to a foot. It is impossible for any one to believe that articulate sounds of ordinary conversation made ten feet from such an instrument can throw its iron diaphragm into such violent vibration as to break contact of the electrodes. I find that talking as far from the instrument as would have any effect upon it in transmitting articulate sound, and then moving up towards the instrument and gradually increasing the volume of voice, increases the loudness of the tones heard in the receiver, but does not change their character. When the mouth of the speaker is brought very close to the instrument, say within an inch or so, and the voice is exerted to the utmost, of course a much more violent vibration is given to the diaphragm, and it is obvious that in that condition breaks will be more likely to occur than in any other. Now, while approaching the voice from a distance of several feet to a distance of six inches, even also raising it somewhat, the character of the sound received at the receiver does not change; but the more violent exertion of the voice, when brought within one inch of the receiver, does produce a change. The change which this produces consists in the production of sounds substantially similar to those which I have caused by various devices for breaking the circuit; and the sounds thus produced by this violent and close application of the voice are not only disagreeably perceived by the ear, but are perceived as quite different from anything which occurs in the articulation up to that point, and distinctly as disturbing and inarticulate noises; as they increase in frequency and extent they drown out conversation. I am convinced from this use of the instrument, that breaks do not occur in the first and distant application of the voice; that they can be made to occur by the violent application of the voice when the mouth is brought extremely close to the instrument; that as the force applied by the voice is increased from the one extreme to the other, there comes a point where, with the more violent exertion, sounds which are distinctly recognized as breaks, or in the nature of breaks, are first heard; and they are heard as disturbances, destructive of articulation to a greater or less degree. With a microphone transmitter properly adjusted for commercial use, I have not found it possible to produce these disturbing breaks with the voice at a distance of much more than ten or twelve inches from the diaphragm; nor are they produced, except accidentally, by any application of the voice such as takes place in a telephone when used in the manner commonly employed for business purposes, and the instrument in ordinary adjustment: and I am sure that any man who expected to be understood by the listener at the other end in the most convenient manner, would not use his voice in the extraordinarily violent manner I have mentioned. I am satisfied from this that whatever it is possible to produce with the instrument in a laboratory experiment by

an operator seeking to ascertain whether he can make it break, breaks will not occur in its ordinary use by a person engaged in transmitting speech by it for commercial purposes, except by accident. Inasmuch as the operation of the instrument, when the voice is applied to it gently and from a considerable distance, is clearly not that of breaking the circuit, it is impossible for me to believe that gradually approaching the voice to it causes any marked change in the nature of its operation, until such time as that change in the nature of the operation is shown in the result; and when any such change appears in the character of the result, it is invariably a change impairing and finally destructive of articulation.

I have also experimented with the following instrument, which clearly excludes the possibility of breaks: —

April 20, 1879, F. K. Fitch patented a form of battery transmitter, which consisted, in the instrument I used, simply of two disks of hard carbon about one and seven eighths inches in diameter, and one eighth to one quarter of an inch thick. The lower one rested horizontally on a bed of wood or vulcanite, and the upper one, which in this case was three sixteenths of an inch thick, was simply laid on top of it. No diaphragm is employed, but the sound waves fall directly on the upper carbon. It appears mechanically impossible that in such an instrument, when so used, the carbons can part contact under the ordinary tones of the voice. Yet, under such circumstances, it transmits intelligible and good speech. This can only be because the variations in the force with which the sound waves press the carbons together vary the electrical conductivity of the contact in substantial accordance with the sound waves.

Subsequently, Prof. Wright made some other instruments of the same type, which he has described in his affidavit in the Ghegan case. They consisted of pieces of hard gas carbon with polished surfaces, varying from two grammes to three quarters of a pound in weight. The contact surfaces of the smallest consisted of a circle five eighths of an inch in diameter, and the largest of a square of three inches. One carbon was laid on top of one or more of the others in the various forms indicated by Prof. Wright's drawing, and speech was directed against the upper one. Under these circumstances, all of these transmitted excellent speech of a pure and clear tone, perfectly good for commercial use. A tuning-fork and resonator were also used as the source of sound. In some cases the stem of the vibrating tuning-fork was also pressed forcibly down upon the upper carbon, and the sonorous vibrations thus mechanically excited gave the pure tone of the fork in the connected telephone receiver. The experiments were varied by placing brass weights of from twenty to seventy grammes on top of the upper carbon, particularly in the case of the large, thin, square carbon. Also, one or two fingers were laid gently on top of the upper carbon, pressing it down upon the other. This slightly diminished the volume of tone, but still

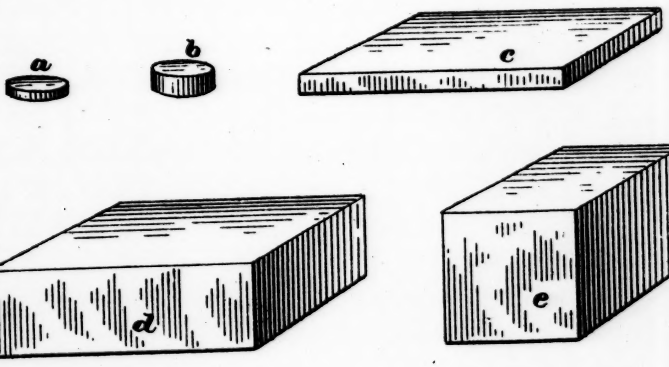


Fig.1. Fig.2. Fig.3.

Fig.4.

Fig.5. Fig.6.

Fig.7. Fig.8.

Fig.9. Scale – Half Size. Fig.10.

left it quite loud enough for practical business purposes, and made the articulation rather more perfect as regards clearness and sharpness of definition, and fidelity and agreeable quality of tone. When a violently vibrating fork was placed on some of the lighter carbons, a scratching noise was perceived; but under all ordinary circumstances we obtained the same pure and clear tone found in all good telephones, and in the defendants' transmitter when in its best adjustment.

The battery used varied from one cell Lelanché, or one cell of Grove, up to four cells of Leclanché, the stronger battery being used with the larger carbons. An induction coil was also used.

Connecting several pairs of these carbons at different times in circuit with one or two cells of battery, and a tangent galvanometer of very low resistance (less than one ohm), moderate pressures exerted by placing the finger on the upper carbon would cause the needle to deflect more strongly, showing that increase of pressure increased the current, and *vice versa*.

These experiments (in addition to many others) show that variations in the force with which one carbon electrode is pressed against the other vary the electrical conductivity of the contact; they also show that such variations in this force as the voice exerts in ordinary speech produce sufficient changes in that electrical conductivity to transmit that speech. This kind of operation is the necessary result of this application of force; it will account for the results produced; no other operation which I can conceive as possible under these circumstances will account for the results.

According to the method described in the fifth claim of Mr. Bell's patent, No. 174,465, electrical undulations similar in form to the sound waves are caused by the sound waves themselves, and then are utilized to produce at the receiving station the same articulate sound. I am sure that it is impossible for any instrument to be so ideally perfect as to reproduce the sound with absolute and mathematical fidelity; and therefore I consider that the method is substantially employed whenever articulate sounds which are recognizably the same as those spoken into the transmitter are produced at the receiver by the employment of current variations (caused by the voice), which are recognizably similar to the sound waves, and which, though to some extent misshapen, deformed, injured, disturbed, weakened or lost, yet produce the same result by reason of so much of the true form as is created and preserved; because in such case the speech is transmitted by reason of the articulating undulations, and in spite of the imperfections thereof.

Int. 49. Since you testified in the Ghegan case, you have, I believe, made some experiments of a similar nature with another microphone provided with a clamp, which you could use or not at

pleasure. Will you please state the nature of those experiments, and what they were?

Ans. I have compared the effects produced by a microphone working in the usual manner, so as to produce variations of current by variations of pressure, with those produced by the same or similar electrodes, when so adjusted or operated as to produce breaks in the current, using a form of transmitter which is furnished with two sets of the ordinary Blake contact pieces of platinum and carbon placed symmetrically on the same face of the diaphragm, one set on each side of the centre and as near to the centre as possible. The two sets of contacts are entirely independent of each other, and each is furnished with the device commonly used with the Blake transmitter for producing the desired normal pressure. Each pair of electrodes is also so arranged that they can be clamped and absolutely prevented from parting contact. The platinum electrodes are attached to the diaphragm and the carbon electrodes are suspended by springs, as is customary with the Blake transmitter. The two sets of electrodes could be used in the same or in separate circuits.

I have tried the following experiments: —

(1.) Placing one pair of the electrodes, which I will call No. 1, in circuit with a battery and receiving telephone, I adjusted the electrodes as is customary for the transmission of speech. On speaking to these in an ordinary tone of voice, good articulation was heard, free from breaks or disturbing noises in the nature of breaks.

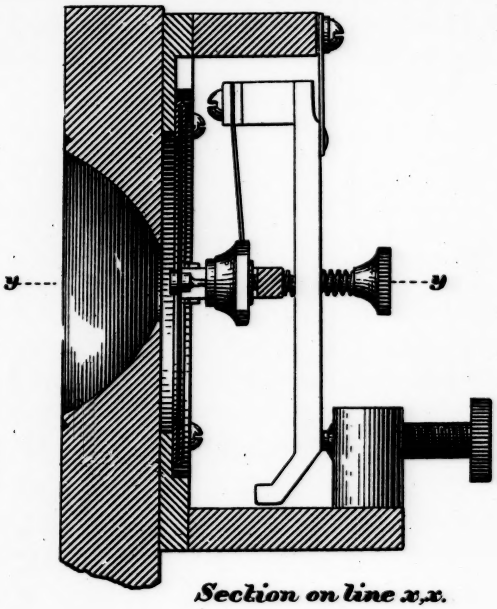
But on speaking louder and louder to the transmitter, disturbances were heard which became stronger and more frequent as the voice was raised, and finally rendered speech unintelligible. These disturbances were of the same character as those which I have observed with circuit-breaking instruments like the Reis transmitter, or with a break-wheel.

When the voice was raised considerably so that great disturbances caused by breaks were heard in the receiving telephone, sparks could be seen by watching the transmitter in a darkened room, and whenever these sparks were seen frequently, the disturbance became excessively great, although very marked interference with speech occurred even before this limit was reached.

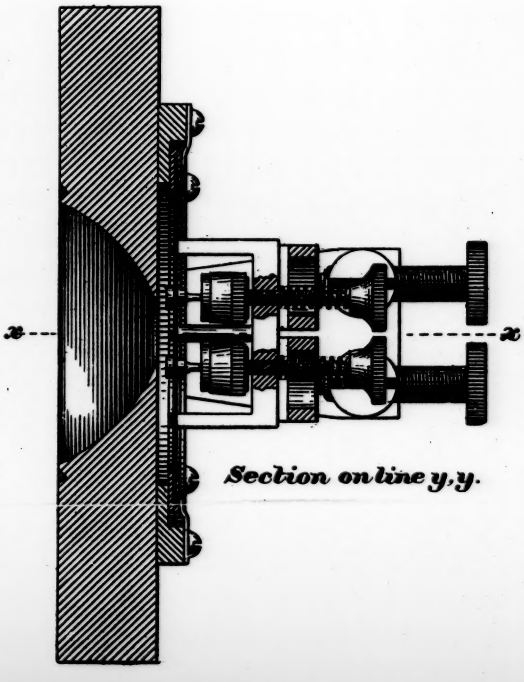
(2.) I then carefully clamped the electrodes (No. 1) so that it

Prof. Cross's Drawing.

(Cross-int. 633)



Section on line x,x.



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was impossible to break the current by the application of a force to the diaphragm. I proved that the current could not be broken thus by tapping the diaphragm violently, pushing it with my finger, and in other ways. Then I spoke to the transmitter more and more loudly. Speech was distinctly reproduced in the receiver, but no sounds of breaks or sounds approaching those due to breaks were heard, nor could any sparks be observed at the transmitter.

(3.) I then unclamped the electrodes (No. 1) and adjusted both pairs (No. 1 and No. 2) so that they were alike as to normal pressure, and both unclamped and in the ordinary adjustment for transmitting speech. Placing each in circuit with a battery and receiving telephone, I found that speech was transmitted clearly and distinctly by both, so that there was no difference that I could detect between them.

(4.) Raising the voice was then found to give the same results in both receiving telephones, speech gradually becoming more and more interfered with as the disturbances increased until it was entirely obliterated in both. Sparks were also seen at both pairs of contacts.

I thus established the fact that these two sets of contacts were exactly alike in their mechanical arrangements, and in the effects which they produced, and, especially, that both transmitted speech in the same way under the ordinary operation of the voice, and that when the voice was applied with such abnormal force as would mechanically tend to produce breaks, the results of these breaks were equally evident and produced the same effect in both.

I then proceeded to alter the conditions of one of them by clamping it in such a way that breaks became absolutely impossible, reasoning that, on repeating the experiment, I should now find, if my views were correct and the disturbances due to breaks, that they would continue to exist in the circuit containing the electrodes which were able to break, and be obliterated in the circuit in which were the electrodes that were not able to break. This I did as follows: —

(5.) I clamped one pair of the electrodes so as to absolutely prevent breaking of the current, leaving the other adjusted as before. On speaking to the transmitter in an ordinary tone of voice,

speech was transmitted by both, and without disturbing sounds. On raising the voice, I found that with the receiver which was placed in the circuit with the clamped electrodes, speech was transmitted as well as ever, and without disturbing noises, while with the receiver placed in circuit with the unclamped pair of electrodes, the disturbing noises due to breaks occurred when the voice was raised, and increased as it was still further raised, until finally speech ceased to be intelligible. Also, sparks were visible between the surfaces of the unclamped electrodes, but not at the surfaces of the clamped ones.

It is clear from this experiment that while one pair of electrodes is producing true undulations, the other is either breaking the current or introducing those violent disturbances which occur as the breaking point is approached.

(6.) I then caused the currents from both pairs of electrodes to be superposed in the same receiver, and found that with an ordinary tone of voice, speech was perfectly transmitted, but as the voice was raised, violent disturbances of the nature of breaks occurred, which interfered with articulation more and more seriously until they destroyed it altogether.

The disturbing sounds observed in the last described experiment were of the same character as those which I have noticed from the operation of a break-wheel producing very short breaks and placed in the circuit of a microphone transmitter when speech is being transmitted.

The instrument used in the investigations which I have described was constructed with great care, so that it was fully reliable as a testing apparatus.

Int. 50. In considering the question whether the defendants' apparatus employs, as the means for transmitting speech, electrical undulations similar in form to the sound waves which act upon the transmitter, of what importance is it to know whether *any* breaks occur in the operation of the transmitter?

Ans. The essential element which must be present in any speaking telephone apparatus is the ability to transmit and reproduce the substantial form of the vibrations characterizing articulate speech, as distinguished from a mere reproduction of the frequency of those

vibrations. This constitutes the essential difference between the method and apparatus invented by Mr. Bell, and all others which preceded it. So far as the practical result to be attained is concerned, the manner in which this characteristic of form is impressed upon the electrical undulations is immaterial.

It is of no importance whether the characteristic similarity in form between the air waves and electrical waves is produced by the variations in electro-motive force due to a magneto transmitter; to the variations in resistance caused by a microphone or other battery transmitter; or if such a thing were possible, by a series of excessively minute breaks produced by a circuit-breaking transmitter. If by any form of transmitting telephone those characteristic variations in form to which the quality of a sound is due are impressed upon an electrical current so that the electrical undulations are similar in form to the sound waves which act upon the transmitter, the method employed is that invented by Mr. Bell, as distinct from the method used by Reis.

Int. 51. What do your experiments show as to whether electrical undulations similar in form to the sonorous vibrations due to a spoken word can, in point of fact, be produced by a series of breaks between contact electrodes actuated by a diaphragm acted on by the voice; and as to whether any breaks which such an apparatus can produce are in fact helpful or hurtful in the transmission of speech?

Ans. My experiments have convinced me of the impossibility of producing such electrical undulations by any apparatus which operates simply by producing a series of breaks between contact electrodes arranged and operated as suggested in the question; and also that any breaks produced between such contact electrodes are never helpful and always harmful in the transmission of speech.

CHAS. R. CROSS.

Attest: CHAS. H. SWAN, *Special Examiner.*

[NEW JERSEY (McDONOUGH) CASE.]

BOSTON, Nov. 15, 1886.

Cross-Examination by S. A. DUNCAN, Esq., *of Counsel for Defendants.*

Cross-Int. 52. You regard the Bell patent of 1876, in one branch of it, as a patent for a speaking telephone, do you not?

Ans. I do.

Cross-Int. 53. What other invention is patented in said patent?

[*Objected to as a question of law.*]

Ans. There is a special form of multiple telegraph described in the patent.

Cross-Int. 54. Also *claimed* in the patent?

[*Same objection*].

Ans. As I understand the claims the apparatus and method employed are set forth as subject matter of the claims.

Cross-Int. 55. In which claims do you find that the apparatus and method employed in the multiple telegraph are set forth?

Ans. In the first four claims, as I understand them; the fifth claim might also be so interpreted as to cover some forms of multiple telegraph.

Cross-Int. 56. You understand the fifth claim to be a claim which relates to the speaking telephone, do you not?

Ans. I do; and if I were interpreting the meaning of the claims I should limit this one to the speaking telephone.

Cross-Int. 57. Then you wish to correct your answer immediately preceding so as to exclude the multiple telegraph from claim five?

Ans. Not exactly that; by my statement in answer to Cross-Int. 55, regarding the fifth claim, I meant that I could see that one might, perhaps, consider claim five as applying to the multiple telegraph. In my answer to Cross-Int. 56, I meant to state that my own interpretation of it would limit it to what is known as the speaking telephone.

Cross-Int. 58. Then this is *your* view of Mr. Bell's claims—that the first four relate to the multiple telegraph as distinguished from the

speaking telephone, and the fifth claim relates to the speaking telephone and does not include the multiple telegraph. Is this correct?

Ans. Not exactly. The 2d, 3d, and 4th claims certainly might apply to the speaking telephone, I should be inclined to limit the first claim to the multiple telegraph, and as I have already said should consider the fifth claim as covering the speaking telephone, and as intended to be limited to it. It might be possible, however, to devise a multiple telegraph which would come within the language of the claim.

Cross-Int. 59. Do you know of any such multiple telegraph?

Ans. I do not know of any which would come within the language of the claim, as I understand it.

Cross-Int. 60. What constitutes the fundamental difference between a multiple telegraph and a speaking telephone?

Ans. As I understand it, the office of a multiple telegraph is to send a number of messages simultaneously; these messages employing the symbols ordinarily used in telegraphy, or others replacing them; while the speaking telephone is intended to transmit human speech from one station to another, and so far as it has practically been employed hitherto, transmits only a single message at a time.

Cross-Int. 61. Does the multiple telegraph act upon the principle of electrical undulations on the line similar in form to vibrations of air used to actuate the transmitting mechanism?

Ans. I cannot answer this question, inasmuch as it appears to me to assume the existence of some specific form of transmitter which is not described in the patent, and whose construction I do not clearly understand.

Cross-Int. 62. Do you know of any multiple telegraph which depends for its operation upon the presence of electrical undulations on the line?

Ans. An example of such an apparatus is shown in Fig. 6 of the patent to Bell No. 174,465.

Cross-Int. 63. Do you know of any multiple telegraph which depends for its operation on electrical undulations on the line produced by, and copying substantially the form of vibrations or the movements of air acting on the transmitter?

Ans. An apparatus which may be thus used is shown in Figs. 4 and 6 of the patent to Bell, No, 186,787.

Cross-Int. 64. What do you mean by the term "speaking telephone"?

Ans. I mean a telephone which is capable of transmitting speech.

Cross-Int. 65. Is the term synonymous with "articulating telephone"?

Ans. I should so understand it.

Cross-Int. 66. Is the fifth claim of Bell's first patent limited to a *speaking* telephone, or is it broad enough to include other kinds?

Ans. I should think that it would include any telephone which transmitted sounds according to the method set forth in that claim, even though the apparatus was not perfect enough, or was not adapted to transmit speech.

Cross-Int. 67. What form of apparatus can you conceive of, which would transmit sounds according to the method set forth in Bell's fifth claim, and yet would not be adapted to transmit speech?

Ans. Such a telephone harp as Mr. Bell described in some of his early publications, in which a number of tuned iron reeds are opposite the pole of an electro-magnet in the transmitter, and a set of similarly tuned iron reeds opposite the end of an electro-magnet in the receiver, would constitute such an apparatus as you refer to in your question. Of course I am not considering at all the practical value of such a device.

Cross-Int. 68. Inasmuch as such a harp mechanism would not be adapted to transmit speech, what would it be good for?

Ans. I will not venture to say what it would be good for practically. It would be possible at least in theory, and I think experimentally, to transmit a sound whose fundamental and overtones correspond to the pitches of the tuned reeds.

Cross-Int. 69. In your direct testimony you have several times spoken of electrical undulations in a telephonic circuit, as "similar in form to the sound waves that act on the transmitter." You of course do not hold that in the apparatus shown in Fig. 7 of Bell's first patent the electrical undulations would be *exactly* similar in form to the sound waves?

Ans. They would be similar in form but the form would not be the same with mathematical exactness.

Cross-Int. 70. Do you know of any telephone in which the electrical undulations on the line are exactly similar in form to the sound waves producing them?

Ans. By "exactly similar" I understand you to mean that the form of the electrical undulation and of the sound vibration are exactly or mathematically identical. I know of no telephone in which this is the case.

Cross-Int. 71. Do you conceive it possible to construct such a telephone?

Ans. Strictly speaking, I do not.

Cross-Int. 72. Would you consider the electrical undulations on the line of an operative telephone as "similar in form" to the sound waves that actuate the transmitter, even though they were to some extent misshapen, deformed, weakened, or even lost?

Ans. The fact that there was a certain deformation of the wave, or even a loss of some portion of it, would not necessarily prevent them from being similar in form.

Cross-Int. 73. Please state to what extent this deformation and loss of portions of the electrical undulations on a telephonic line may occur without departing from Bell's method, referred to in the fifth claim of his first patent?

Ans. I do not know how to give a definite answer to this question, for it is much as if you asked me how great an amount of lisping or stuttering, or how broad a brogue would be permitted before the air waves produced by such defective or peculiar utterance would cease to be similar in form to those characterizing the English language as properly spoken. It seems to me that Mr. Bell's method is employed so long as the work done is done in virtue of such similarity in form as exists between the sound waves and the electrical undulations, and in spite of, rather than because of such dissimilarity as exists. Practically, however, even a slight departure from the most exact similarity in form that we can produce, causes indistinctness and uncertainty in the articulation transmitted.

Cross-Int. 74. Is there no practical method of determining whether in any particular apparatus the deformation and loss of por-

tions of the electrical undulations have reached such a point as to place the apparatus outside the scope of Bell's fifth claim, or, in other words, so that the apparatus will cease to operate upon the method referred to in that claim?

Ans. If an actual piece of apparatus, which could be experimented with, were produced, it would be possible to determine whether it did or did not operate according to the method described in the fifth claim.

Cross-Int. 75. What would be the practical test?

Ans. One would observe the construction of the apparatus, the mode in which it was intended to operate if this were stated, and the results actually obtained as apparent to the ear.

Cross-Int. 76. Could you determine the question by the last test alone?

Ans. I have not found any difficulty in determining it in any apparatus that I have ever seen.

Cross-Int. 77. Now please state how, in the various telephone mechanisms that you have seen, you have always been able, by attention alone to the results obtained in using such mechanisms, to determine whether or not the electrical undulations were so far deformed or lost as to place the mechanism, and the method of its operation, outside Bell's fifth claim.

Ans. It is of course difficult to describe the sensations produced upon the ear. In the telephone apparatus in which it is evident that the method set forth in Bell's fifth claim is employed, more or less perfect articulation is heard at the receiver, which is free from or at least predominates over other sounds which may be present, and which result from the deformation. In apparatus in which clearly the method of that claim is not employed, disturbing sounds or noises predominate over or destroy the effect due to the electrical undulations. I cannot in description draw a sharp line of demarcation between the two kinds of apparatus, because it is possible to pass by easy gradations from the utmost similarity between the aerial and electrical undulations, to the greatest dissimilarity between them.

Cross-Int. 78. Then in applying this particular test (which I understand you to say has always been sufficient, practically, in the case of the various mechanisms which you have been called upon to ex-

amine), I understand that you are governed by the distinctness of the articulation as you observe it. Is this a fair statement of this mode of testing an apparatus to determine whether it is within Bell's fifth claim?

Ans. I do not think that this is a fair statement, although of course distinctness is one element. The question is one concerning the form of the wave, and the differences are those differences which are due to differences in form. It seems to me that your questions although based on my previous answers, are really leading me a little away from the subject matter of those answers. I had intended to be understood as saying that in all the telephonic apparatus which I have been led to examine, I have been able to tell by the ear whether the method of Bell's fifth claim was or was not employed. Doubtless it would be possible to construct an instrument, or to so operate existing instruments, that it would be difficult to say, from the evidence of the ear alone, whether that method was or was not theoretically employed.

Cross-Int. 79. In thus testing the various mechanisms heretofore examined by you, have you ever found one in which the articulate sounds uttered at the transmitter were reproduced at the receiver with sufficient distinctness to be recognized, which you did not pronounce to embody the mechanism and employ the method of Bell's fifth claim?

Ans. I understand you to ask me substantially whether I have ever heard a telephone transmitting articulate speech recognizably, which did not employ the method set forth in Bell's fifth claim. I have not.

Cross-Int. 80. Whenever you examine a new telephone and find that articulate sounds spoken at the transmitter are recognizably reproduced at the receiver, does not this fact in your mind justify the conclusion that the apparatus embodies the invention of Bell's fifth claim?

Ans. Inasmuch as I know of no telephone capable of transmitting articulate speech which does not employ that method, I should of course consider that there was the strongest presumption that any new form of speaking telephone which I observed to operate successfully also made use of this method. It is my custom, however, in

examining any telephone apparatus to observe the construction of the apparatus before testing its operation.

[*Adjourned.*]

NOVEMBER 16, 1886, 11 A. M.

Cross-Int. 81. I do not think the last question fully answered. Please state whether to your mind the fact that with any particular apparatus articulate sounds spoken at the transmitter are recognizably reproduced at the receiver does not justify the conclusion that that apparatus employs the method of, and is the apparatus referred to in Bell's fifth claim of the patent of 1876?

Ans. I am not certain that I understand the terms of the question in the precise sense in which they lie in your mind. I judge, however, that by "articulate sounds" you mean articulate speech such as a sentence or a paragraph, and not merely some ejaculation or fragmentary syllable for which an inarticulate sound might easily be mistaken. I suppose also that the recognition which you refer to is a recognition by means of the articulate elements which are transmitted, that is by the quality of the sound transmitted, and not a mere guessing from rhythm or accent, or anything of that kind.

Understanding your question in this sense I should say that if I recognized articulate speech by its quality by means of a telephonic apparatus, both the transmitter and receiver of which were unknown to me, I should feel the utmost confidence that the recognition was effected because of the employment of Mr. Bell's method by the apparatus used.

My reason for this confidence would lie simply in the fact that with all the speaking telephone apparatus with which I am familiar, Mr. Bell's method is employed, and I know of no other method available for the purpose. I should also judge the apparatus to be of the kind set forth in the fifth claim of the Bell patent; assuming of course that the electrical undulations by which the transmission of speech is secured, are set up by the action of the sound waves to which they are similar.

Cross-Int. 82. A single spoken word is as truly articulate speech, as one of Evarts' or Cicero's periods, is it not?

Ans. If intelligibility is the test, that is doubtless the case. There are some words however which are so simple in their nature, that I should hardly know how to distinguish them from inarticulate sounds; some words, for example, consisting of a single vowel.

Cross-Int. 83. What is "articulate speech"?

Ans. I understand by articulate speech spoken words and sentences consisting of the different vowel and consonant elements, and such as are ordinarily used for the communication of ideas.

Cross-Int. 84. Now, can you give a definition of the term "articulate sound"?

Ans. I am not in the habit of using this term myself, and if I found it used, I should probably judge of its meaning according to the context. Thus, when you have used it in some of your previous questions, I have supposed it to be equivalent to the term "articulate speech." The difficulty in giving a rigid definition comes from the fact that it is not easy to say when a sound of the voice ceases to be articulate. I do not know but that the intention of the person uttering it might justify us in calling the same sound at one time articulate and at another inarticulate, although there were no perceptible physical difference between them. An articulate sound must, I should say, be produced by the organs of speech, although not every sound produced by the organs of speech is articulate.

Cross-Int. 85. You have made a careful study of the science of acoustics for several years past, have you not?

Ans. I have done so.

Cross-Int. 86. As professor of physics, you lecture upon that subject before your classes?

Ans. I do, before certain of them.

Cross-Int. 87. Would it be accurate to define an articulate sound as one which is capable of being joined or articulated with other sounds so as to produce speech?

Ans. I should not feel satisfied with that definition. I should think some sounds at least could hardly be called articulate until they were actually *articulated* with other elements to form a syllable or a word. It is almost impossible to frame a rigid cut and dried definition for terms of this kind.

Cross-Int. 88. Let me try to help you by proposing the following definition, taking the suggestion therefor from your last answer: Would you be satisfied to define an articulate sound as any one of the component sounds of actual speech?

Ans. I do not fancy the definition, because I do not think that the words "articulate sound," as they have been used or might be used, would necessarily conform to it. I think the terms "articulation" and "articulate speech" are more common than the term "articulate sound," which I should say, would be more likely to be used in a general sense than in the limited sense implied in your definition. A complete word might very well be spoken of as an articulate *sound*, although there were various elements or *sounds* united together to form it. My objection to your definition arises largely from the fact that the term which you seek to define is not, as far as I am aware, used in the very definite manner which you assume. Its use is quite indefinite as far as I know.

Cross-Int. 89. As you seem to take exception to the two definitions of the term "articulate sound" proposed in my last two questions, I will ask you to give a definition of the term which will be more satisfactory to your own mind.

Ans. The part of a critic is a comparatively easy one to play, and I have already in my answer to Cross-Int. 87, stated my views as to the difficulty of giving a rigid definition on this point. The term "articulate sound" had best be used, I should say, to express a series of sounds joined together; such as we have, for example, in a complete word or a complete syllable. I do not, however, consider this a satisfactory definition. It perhaps falls into the error of vagueness, in endeavoring to avoid the undue rigidity which I criticised in your more precise definitions. I suppose, however, that what we really want to understand is the meaning of the term so far as it has been used, rather than to impose a definition according to which it must be used in the future.

Cross-Int. 90. You have frequently used the term "articulate speech." How does this term, as you have used it, differ from the simpler term "speech"?

Ans. The term "articulate speech" has always seemed to me somewhat tautological, as I suppose there is no such thing, properly

speaking as inarticulate speech. Articulate speech is a term which is very commonly used, however, and I suppose conveys and impresses upon one the idea of the articulation which characterizes speech, as the word "speech" alone does not.

[*Recess.*]

Cross-Int. 91. How do you define the term "speech"?

Ans. The combination of vocal sounds which serve for the communication of ideas; using those spoken words which are employed by common consent as the symbols of our ideas.

Cross-Int. 92. You seem to object to the use of the term "articulate sound" as inexact, and, I suppose, unphilosophical. Do you recognize the distribution of sounds into the two classes of "noises" and "musical sounds" as philosophical and as exhaustive?

Ans. That distribution is a common one, and though necessarily inexact, is a convenient one in many cases. There is, however, no definitely marked line of demarcation between the two, and were one forced to define them he would have to be somewhat vague.

Cross-Int. 93. Take the sounds of the human voice in ordinary conversation, how would you classify them—as "noises" or as "musical sounds?"

Ans. If I were called upon to classify them in this manner, I should include them among musical sounds, although I have heard many voices to which it seems rather a stretch to apply that term. The term "musical sound" as used by the physicist, is sometimes in rather sharp contrast to the same term as used by a musician.

Cross-Int. 94. Why do you classify the sounds of the human voice in ordinary conversation as musical sounds?

Ans. Because they present a pretty definite quality according as one or another vowel sound is used. There is considerable regularity in their vibrations, and the effect upon the ear is pleasant rather than otherwise. In some languages these musical characteristics are very clearly marked, in others less so; but in those languages with which I am familiar, it seems to me that we may consider the sounds as musical on the whole, rather than as harsh and noisy on the whole.

Cross-Int. 95. "Noises," as well as "musical sounds," have qualities of their own, have they not?

Ans. They have.

Cross-Int. 96. Due to the same cause as in the case of musical sounds?

Ans. Yes.

Cross-Int. 97. Briefly stated, what is the cause of the quality of the sound, whether it be a noise or a musical sound?

Ans. Quality differences are due to differences in the pitch, number and relative intensity of the different partial tones which make up the complete sound. By "partial tones" I mean the fundamental and overtones.

Cross-Int. 98. Then "quality" or *timbre*, as I understand you, is not a characteristic of sound which is coördinate with intensity and pitch, but is the effect of the particular combination of the fundamental and overtones that happens to characterize the particular sound whose quality is observed, and is dependent upon the two characteristics of intensity and pitch in the various partial tones?

Ans. That is true. We can reproduce a certain quality of tone artificially by combining separate sounds having the same pitch and intensity as the partial tones of the sound to be reproduced.

Cross-Int. 99. Do you understand that there is any substantial difference between noises and musical sounds, so far as regards their complexity?

Ans. Broadly speaking, the vibrations in musical sounds are more regular than in noises, but one runs into the other by insensible gradations. In musical sounds the partial tones as a whole form consonances with one another, while in noises they form dissonances with one another.

Cross-Int. 100. Having regard to the number of partial tones that are sensibly present, which class of sounds ordinarily is the more complex, a noise or a musical sound?

Ans. I do not think that I can answer this question definitely. The essence of the musical sound is the predominant consonance of its partial tones, that of the noise the dissonance of its partial tones. Either the noise or the musical sound might therefore have the

greatest number of partial tones. It is more difficult to pick them out with the ear, however, in the case of the noise. I do not know that I can say more than that some musical sounds are more complex than some noises, while certain noises are more complex than certain musical sounds.

Cross-Int. 101. Is it then more difficult to recognize the quality of a noise than the quality of a musical sound?

Ans. If you mean to recognize it, as a whole, by the ear, it is not; except in so far as there is less definiteness about noises, as a whole, as to quality, than with musical sounds. If, however, you ask me whether it is more dificult to analyze a noise into its elements than a musical sound, I should say, answering very broadly, and excluding various specific cases, that it is.

Cross-Int. 102. Would the fact that there is "less definiteness about noises, as a whole, as to quality, than with musical sounds," tend to render it more difficult to recognize the quality of noises than of musical sounds?

Ans. What I meant by my statement as to the lack of definiteness in the quality of noises was, that we have not classified them as well as we have classified musical sounds, and also that we do not distinguish as readily between different dissonances such as are present in noises, as we do between the different consonances which characterize musical sounds. I should say, therefore, that we are more likely to confound noises than musical sounds. Thus we may mistake the rumbling of a cart for the sound of thunder, or the cries of a cat for those of a baby.

Cross-Int. 103. When, in your answer to Int. 7, you define quality as being "that peculiarity of a sound by which, independently of its pitch or loudness, we are enabled to determine the instrument by which the sound is produced," you did not mean of course to imply that quality is not dependent upon the pitch and loudness of the various partial tones making up the sound?

Ans. I did not.

Cross-Int. 104. Is it "quality" which enables you to distinguish the sound of any instrument from the sound of the human voice, the sounds being not different in pitch and loudness?

Ans. It is.

Cross-Int. 105. Is it by quality also that you distinguish one voice from another, or a sound uttered by one voice from another sound uttered by the same voice?

Ans. Very largely, though not wholly. In distinguishing the voice of one person from that of another, we are aided very greatly by the manner of enunciation, of intonation, of emphasis, and various other peculiarities apart from those which give its characteristic musical quality to the sound.

Cross-Int. 106. How do these various personal peculiarities, which you refer to, modify the sounds of the voice otherwise than by modifying the intensity and the pitch of some or all of the partial tones that make up the complete sounds?

Ans. Doubtless such differences as these may very largely be resolved into such differences as you mention in your question. Besides this, however, there is the mode of beginning or ending of the sounds, whether sudden or gradual; also there is the rate at which the person habitually speaks.

Cross-Int. 107. How can any particular mode of beginning or ending a sound be manifested to the human ear, except through the special variations of intensity and pitch produced thereby in the partial tones of such sound?

Ans. For example, by suddenness in beginning or by suddenness ending, as distinguished from a gradual rise or fall of intensity.

Cross-Int. 108. Will not suddenness in beginning or ending a sound produce different air vibrations from what would occur with a gradual beginning or ending; different, I mean, not necessarily as to the fundamental vibration, but at least as to some of those that relate to the overtones?

Ans. I should not think that the single element of suddenness, apart from any other differences which might accompany it, would necessarily affect the overtones.

Cross-Int. 109. Certainly a sudden beginning will in some way change some of the air vibrations, as compared with a gradual beginning, will it not?

Ans. They will attain more rapidly to their maximum amplitudes.

Cross-Int. 110. In other words, the first vibrations produced in the two cases will differ as to their amplitudes?

Ans. That is true.

Cross-Int. 111. Now, is it not a fact that the quality of all sounds whatsoever, whether noises or musical sounds, articulate sounds or inarticulate, is dependent upon the intensity and pitch of the various partial tones which respectively compose them? Or, in other words, upon the amplitude and rate of the air vibrations that produce such respective partial tones?

Ans. It is. I have pointed out in my previous answers certain facts as to the so-called non-musical elements of quality, merely because I have sometimes known erroneous conceptions to be formed from overlooking them.

[*Adjourned.*]

NOVEMBER 18, 1886, 11 A. M.

Cross-Int. 112. Referring to your answer to Cross-Int. 81, do you mean to be understood as saying that if you were to recognize the articulate elements of spoken words by means of a telephonic apparatus, the transmitter and receiver of which were unknown to you, you would, from that fact alone, be justified in concluding that the speech thus recognized is transmitted by means of electrical undulations similar in form to the air waves that influence the transmitter; and that such apparatus is the apparatus referred to in the fifth claim of the Bell patent of 1876, and operates by the method therein set forth?

Ans. I should find it much easier to answer this question after actually listening to the transmission secured with a given apparatus, than I find it to answer with reference to imaginary apparatus. A part of my difficulty arises from the fact that I do not know precisely what meaning to attach to the term "articulate elements of spoken words," and also from the fact that we may oftentimes recognize crude imitations of spoken words when these are familiar to us. Illustrations of this last fact are observed in the various forms of talking machine, and in the phonograph.

I should not therefore feel ready to say that if I thought I recognized some sound that approximated more or less closely to a simple

word or syllable, or fragment of a syllable, that accurate electrical undulations, rather than simply some approximation to these, were employed, nor that the apparatus was certainly that referred to in the fifth claim of the Bell patent of 1876.

[*Answer objected to as not responsive.*]

Cross-Int. 113. What do you mean in this answer by "accurate" electrical undulations?

Ans. I used this word, not thinking of any better one, to indicate such electrical undulations as are close copies of the air vibrations as distinguished from cruder imitations of these, such as might be built up, for example, artificially. The distinction which I had in mind might be illustrated, though, perhaps, somewhat crudely, by the distinction between a full and a dotted sinuous line, or between a complete surface and a surface made up of ruled parallel lines tolerably near together. These two resemble each other to a considerable extent, and with simple figures and at a considerable distance from the eye, one might be mistaken for the other. So I might recognize the coarsely hatched drawing of a letter as being that letter, although even a casual inspection might show that it was a very imperfect imitation. So, again, a very sparsely dotted letter might be recognized, while if a sentence were written in that manner it might be quite unintelligible.

Cross-Int. 114. Do you then intend to indicate, by your last two answers, that it is possible under any circumstances, to transmit speech electrically, without the employment of electrical undulations, and thereby using the method of Bell's fifth claim?

Ans. I do not know that I can say more with regard to this than I have already said, namely; that I know of no other method of transmitting speech in any proper sense. I did not intend to indicate that I though it possible to transmit speech electrically without the employment of electrical undulations.

Cross-Int. 115. Do you regard it as a physical law that a telephone can operate in the transmission of speech, only by means of electrical undulations substantially similar in form to the air waves that actuate the transmitter?

Ans. If I understand you correctly, you ask me whether I consider it a necessary consequence of the laws of physics, that speech

can be transmitted electrically only by the employment of such electrical undulations as you mention in your question. I have not succeeded of thinking of any other way of doing this, and it does seem to me to be a necessary though not an immediately evident consequence of natural laws.

Cross-Int. 116. Do you know of any experimental mode of examining the current of a telephone—so as to determine whether it be undulatory, pulsatory or intermittent—otherwise than by means of the instrument at the receiving end, whereby the sounds transmitted over the line are reproduced to a greater or less extent?

Ans. I have imagined some methods by which this might be done, but they are very delicate, and I have not tried to put them in practice. There is also a device, which has been used, I believe, to a slight extent, for the study of telephone currents, which I have intended for some years to work up myself, and by means of which, I think, we could distinguish between the different kinds of currents which you mention. I have not, however, experimented with any apparatus for detecting these differences in the nature of a current, otherwise than a telephonic receiver applied to the ear.

Cross-Int. 117. Do you know of any person who has been able to determine experimentally the nature of the telephonic current, otherwise than by the use of the receiver applied to the ear?

Ans. I do not.

Cross-Int. 118. If a telephone be spoken into, and you can distinguish a single word at the receiver, would such a telephone embody the method and apparatus of the fifth claim of Bell's patent of 1876?

Ans. To the extent in which the word was recognized by the quality of the sound, I should think that such an apparatus would employ electrical undulations similar in form to the air waves producing them, and hence to that extent would embody the method of the fifth claim. Without, however, hearing or having described any specific apparatus or results, I do not feel ready to say that the fact that I succeeded in making out some word, without respect to its character, would justify me in concluding that the apparatus necessarily embodied the invention set forth in the fifth claim.

Cross-Int. 119. Do you then pretend that you can make out or recognize a word in a telephonic receiver otherwise than by observing its "quality"?

Ans. Perhaps not, if the word "quality" is used in its very broadest sense, including the manner of beginning and ending the sound. I ought to say that in my last answer I also had in mind the question of the influence of the expectedness of a word.

Cross-Int. 120. If then while listening to a telephonic receiver you were to recognize a single word not expected by you, and one composed of several component sounds (this being not a mere ejaculation) would the telephone in your opinion embody the invention set forth in the fifth claim of Bell's patent of 1876?

Ans. Still remembering the fact that you are questioning me with regard to a purely hypothetical apparatus, I will say that if I really and distinctly recognized a spoken word which was unanticipated, and of such a nature that I could not have guessed it, its quality being evident; then, not being myself acquainted with any means of securing this result other than by the production of electrical undulations similar in form to the sound waves producing them, I should, in the absence of evidence to the contrary, conclude that the transmission was secured by the production of electrical undulations substantially similar in form to the air waves producing them, and so that it embodied the invention of the fifth claim.

[*Recess.*]

Cross-Int. 121. Do you regard that as an affirmative answer to the question?

Ans. I intended my answer to be affirmative, subject of course to the various limitations which I expressed in it, and which though not explicitly stated in your question, I supposed to be implied in it.

Cross-Int. 122. You are aware of the fact that speech can be transmitted by a transmitter consisting of three carbon blocks, one of the three being connected with the battery, another with the line, and the third resting upon these two?

Ans. I am.

Cross-Int. 123. Have you ever used such a transmitter?

Ans. I have done so.

(N. J. McDONOUGH)

Cross-Int. 124. Transmitting speech successfully by means of it?

Ans. Yes.

Cross-Int. 125. You are familiar with that form of the Hughes microphone which is made by the use of three nails arranged in the same manner as the carbon blocks just referred to?

Ans. I am.

Cross-Int. 126. Can speech be transmitted to any extent by means of such a microphone?

Ans. I do not remember to have done this myself. I believe that it is said to have been done to a certain extent, but I do not know how well.

Cross-Int. 127. Have you ever tried this mechanism?

Ans. I never tried three nails alone, so far as I can remember, but I recollect that when Prof. Hughes's article was first received in this country, and before I had seen it, I was told of its contents in a somewhat indefinite manner, and I piled up a number of nails to try them as a transmitter. I did not get at all good results, but this may partly have been due to the fact that the only receiver which I then had was a very poor one. I do not remember to have tried that precise experiment since.

Cross-Int. 128. Have you any doubt that speech has been and can be transmitted with Hughes's three-nail microphone?

Ans. I see no reason to doubt the fact.

Cross-Int. 129. If Hughes's three-nail microphone were used for the transmission of speech, or if the carbon block transmitter spoken of in Cross-Int. 122 were used for such a purpose, would the instrument embody the invention set forth in the fifth claim of Bell's patent of 1876?

Ans. It would, in my opinion. I understand, of course, that the devices are operated as in the ordinary transmission of speech by a microphone.

Cross-Int. 130. Do you know of any method of adjusting a Blake transmitter so that it will operate efficiently, otherwise than by listening to a receiver joined in the same circuit?

Ans. Not of any method which would be a practical one, and satisfactory. I know of no other which has been used.

Cross-Int. 131. Can you tell by merely looking at the Blake tnrasmtteir whether it is so adjusted as, when spoken to, to produce

electrical undulations in the circuit similar in form to the air waves acting on the transmitter?

Ans. I do not think that I could tell certainly by simply looking at it when it was not being operated, which I assume to be the condition supposed by your question. I think that I could adjust it, if I could see the electrodes, so that it would produce such undulations; though I do not suppose that I could so adjust it as to give the best results in transmission. I have never tried to adjust the instrument in this manner, however, and so may be mistaken in my impression.

Cross-Int. 132. If you were endeavoring to transmit speech with a Blake transmitter so adjusted that it would not transmit speech, would the apparatus embody the invention of the fifth claim of Bell's patent of 1876?

Ans. I should think that would depend upon how it was adjusted. If it failed to transmit speech because it did not transmit any electrical undulations, or because those which it did produce were not similar in form to the sound waves producing them, I should not think it would embody the method and apparatus of that claim. If it failed to transmit speech because the proper electrical undulations, though produced, were too feeble to enable us to recognize what was transmitted, I should then think, as far as scientific identity was concerned, that it did embody the method and apparatus of that claim.

Cross-Int. 133. Now, if a Blake transmitter, or any other telephonic apparatus, should be so adjusted or organized as to cause the current to act upon the receiver otherwise than by electrical undulations, or by undulations not similar in form to the air waves that actuate the transmitter, but so as to reproduce speech; would you say that such an apparatus embodies the invention of Bell's fifth claim?

Ans. I cannot conceive how a Blake transmitter can be adjusted to perform any such operation as you suggest. If in your hypothetical apparatus speech were reproduced other than by the operation on the receiver of electrical variations, which are substantially electrical undulations similar in form to the sound waves producing

them, I should not think the apparatus did embody the invention referred to.

Cross-Int. 134. I suppose that you would insist upon it that *any* electrical "variations" which are capable of so influencing the receiver as to cause it to reproduce speech, would be "substantially electrical undulations similar in form to the sound waves producing them?"

Ans. I know of no others which will reproduce speech, and hence should expect to find them so if speech were reproduced.

Cross-Int. 135. You know it to be a fact, do you not, that the electrodes of a Reis transmitter can be so adjusted relatively to each other, by the mode in which the instrument is talked to, that it will transmit speech?

Ans. I have been able to transmit speech intelligibly by speaking gently to a Reis transmitter in circuit with a battery and Bell magneto receiver.

Cross-Int. 136. At such times, as you understand it, the Reis instrument is producing electrical undulations similar in form to the air waves?

Ans. It is.

Cross-Int. 136. And embodies the invention of Bell's fifth claim of the patent of 1876?

Ans. I understand that it does when so operated.

Cross-Int. 137. Both the method and the apparatus of that claim?

Ans. I should say that it does.

Cross-Int. 139. Did you find that you were also able, with that same Reis transmitter, to so adjust the electrodes in their relation to each other, simply by your mode of talking to it, that it would not transmit speech?

Ans. When I talked to it loudly, so that the circuit was broken frequently, I was unable to transmit speech by it.

Cross-Int. 140. Did it at such times embody the invention of Bell's fifth claim?

Ans. I should say that it did not.

Cross-Int. 141. Then, according to your belief, the determination of the question, whether or not a Reis transmitter embodies

the invention of the fifth claim of Bell's patent of 1876, does not depend on the *construction* of the instrument or the relation of the parts to each other when at rest, but upon *the mode in which the instrument is used*. Is that correct?

Ans. It is.

Cross-Int. 142. Referring now to the Mayer diagrams in your answer to Int. 11, you understand, do you not, that the lower diagram *c d* is the correct graphical representation of a sound wave produced by the fundamental and the overtones whose curves are represented at *a b* in the upper diagram?

Ans. I do.

Cross-Int. 143. Let us assume now a sound wave whose form is correctly represented by Mayer's diagram *c d* and that this wave impinges upon the transmitting diaphragm of a theoretically perfect telephone, would this same curve or diagram *c d*, correctly represent the form of vibration of such diaphragm?

Ans. I should say that it would substantially.

Cross-Int. 144. Would that also be true of the electrical undulations produced thereby?

Ans. Substantially true. There may of course be what are called "variations in phase" among the component vibrations, which will not, however, alter the mathematical nature of the curve, although they would alter its appearance to the eye.

Cross-Int. 145. And would the movements of the receiving diaphragm be expressed by the same curve?

Ans. Substantially so. There will of course be such phase differences as I have mentioned; but the mathematical character of the curve would remain the same.

Cross-Int. 146. Referring now to the movements of the transmitting diaphragm, can you assign any particular portion of Mayer's curve *c d* to the advance of the diaphragm under the condensation of the air, and any other portion to its recession?

Ans. We can so interpret the curve as to do this. Thus, considering the motions of the central portion of the diaphragm, we may suppose that while the ordinates are increasing, such portion is moving towards the magnet, and that while they are decreasing, such portion is moving from the magnet.

Cross-Int. 147. Then with that interpretation of the Mayer curve *c d* as applied to the movements of the diaphragm of a contact transmitter, what is the significance of the minor curves or sinuosities in those portions of the general curve which you say represent the recession of the diaphragm?

Ans. In a microphone transmitter, such as I understand you to refer to, these sinuosities would correspond to variations in the pressure between the hammer and anvil electrodes.

Cross-Int. 148. I intended to inquire as to the significance of those minor waves or sinuosities with reference to the actual movement of the diaphragm.

Ans. They indicate that while the diaphragm is performing its long backward movement, which, as a whole, is one of recession, there is superposed upon this motion a lesser vibration in virtue of which the diaphragm moves a little forward, and then further back repeatedly.

Cross-Int. 149. In other words, where the portion of the curve which indicates the general backward movement of the diaphragm turns slightly forward, this indicates that at that point the diaphragm itself is making a slight advance movement in connection with, or, if you please, as a short interruption of, its general retrograde motion?

Ans. I so understand it.

Cross-Int. 150. If now we consider Mayer's curve *c d* as representing the movements of the diaphragm of a Reis transmitter when actuated by a sound wave whose components are represented by Mayer's curve *a b*, and that such sound wave has sufficient energy to cause the electrodes of the instrument to separate, at what point along said curve *c d* will such separation taken place?

Ans. I should expect it to take place at or near the extreme upper limit of the curves, though I am not quite certain that it would not take place before this, as there might be some effect from the elasticity of the electrodes.

Cross-Int. 151. Assuming that the separation of the electrodes continued for the twentieth part of the time occupied by an entire vibration of the diaphragm, at what point on the curve *c d* would contact be renewed?

Ans. I should think, at a rough estimate by my eye, pretty near the rise of the first sinuosity after the curve has begun to fall.

Cross-Int. 152. Then would the short upward movement of the diaphragm, represented by the first sinuosity, bel ikely to produce another but shorter separation of the electrodes?

Ans. It might or might not do this, according to the violence of the vibrations.

Cross-Int. 153. If it did not, would the upper electrode probably follow down in contact with the other electrode as the diaphragm recedes?

Ans. If it did not part contact, it would.

Cross-Int. 154. In the last few questions referring to the Reis transmitter you have had in mind the cubical box form of instrument, have you not?

Ans. I did not mean to limit any answers to that particular form, though I think that, so far as either was definitely before my mind, it was the cubical box form.

Cross-Int. 155. That also is the form with which you have successfully experimented in the transmission of speech?

Ans. I have used this form as a transmitter successfully with a Bell magneto as a receiver.

Cross-Int. 156. Did you ever transmit speech with it to any extent, using Reis's knitting-needle receiver?

Ans. Not satisfactorily. I once succeeded, using great care and making every possible exertion to secure success, in understanding one very brief, familiar, and rather looked-for sentence, which the person speaking to me was in the habit of using when testing inefficient instruments; and also a portion of another short, familiar, and anticipated sentence. This is the most that I have done with the instrument.

Cross-Int. 157. What were the words that you heard?

Ans. As I recollect them, the sentence referred to was "The sun is shining brightly." I also heard, "It is half past ——," it really being half past four, I think. The exact details of this experiment are not fresh in my mind, as it is a long time since I tried it; but in a former deposition in one of the telephone cases, I have stated them more at length.

[*Adjourned to Friday, Nov.* 26, *at* 10 *A. M.*]

DECEMBER 2, 1886.

Cross-Int. 158. In Cross-Int. 150 I assumed the Mayer curve *c d* to represent the movements of the diaphragm of a Reis transmitter as actuated by a sound wave whose components are represented by Mayer's curves *a b*, and that the energy of such sound wave was sufficient to cause the electrodes of the instrument to separate; now please state whether during those portions of the time occupied by each vibration of the diaphragm during which the electrodes are in contact, there is any variation in the pressure of the electrodes upon each other?

Ans. There is.

Cross-Int. 159. What causes this variation of pressure?

Ans. The inertia of the anvil electrode of the Reis instrument.

Cross-Int. 160. Please explain a little more fully.

Ans. When the upward velocity of the hammer electrode is increasing, the inertia of the anvil electrode prevents it from immediately acquiring the velocity of the hammer electrode, so that the pressure between the two electrodes is increased. When the velocity of the hammer electrode is diminishing, the anvil electrode tends to move onward more rapidly on account of its inertia, so that there is a diminution of pressure between the electrodes. If the hammer electrode is descending and its velocity increases, the inertia of the anvil electrode will prevent it from following the hammer electrode so rapidly, so that a diminution of pressure will result.

Cross-Int. 161. And what will be the effect upon the pressure between the two electrodes of those peculiar movements of the diaphragm which are represented by the minor sinuosities of that part of Mayer's curve *c d*, which as a whole represents the general retrograde movement of the diaphragm?

Ans. Unless the two electrodes parted contact, there would be variations in pressure corresponding to the movements represented by the minor sinuosities.

Cross-Int. 162. What will be the effect upon the current of these variations of pressure between the electrodes, which you say would occur during those periods of time when the electrodes are in contact?

Ans. Variations in the strength of the current would be produced.

Cross-Int. 163. What effect would these variations in the strength of the current have upon the *loudness* of the sound produce ! at the receiving end of the line?

Ans. If you assume that the Reis transmitter is so operated as not to break the circuit at each principal vibration, then these variations in the strength of the current would produce variations in the loudness of the sound produced by the receiver.

Cross-Int. 164. My last question proceeded upon the hypothesis that characterizes the several preceding questions, to wit: that the instrument is so used that contact of the electrodes is not preserved during the entire period of the vibration. I understand you to have said that, under this hypothesis, there will be variations of pressure between the electrodes during those periods of time when contact is preserved, and that these variations of pressure will produce variations in the strength of the current. I now ask you whether these variations in the strength of the current will produce any effect whatever upon the loudness of the sound emitted by the receiving instrument?

Ans. They will produce a certain effect, and mechanically considered, the strength of the sound, that is of the air wave produced, will vary. Practically, however, the excessive loudness of the sound produced on breaking the circuit impresses the ear so strongly as entirely, or almost entirely, to mask the subjective effect of these minor variations.

[*Recess.*

The last sentence of the foregoing answer is objected to as relating to a matter not pertinent to the subject inquired about.]

Cross-Int. 165. What particular form of Reis transmitter have you had in mind in answering the last few questions?

Ans. The cubical box form of transmitter, and the knitting needle receiver.

Cross-Int. 166. Do you understand that there is any material difference in mode of operation between the three principal forms of the Reis transmitter, to wit, the bored-block instrument, the cubical box instrument, and the Reis-Legat transmitter, either as to the alleged fact of the electrodes separating as the diaphragm vibrates, or

as to the further fact of there being a variation in pressure between the electrodes, with a consequent variation in the strength of the current during the time when contact is preserved?

Ans. In all three forms, when operated as described in the Reis publications, which I understand to be the mode of operation assumed in your question, there is a break of contact between the hammer and anvil electrodes at each principal vibration. In all three forms there are variations in the pressure between the two electrodes during the time that these are in contact.

Cross-Int. 167. Is there any substantial difference between these three forms of Reis transmitters as regards the relative length of the periods of contact and of separation of the electrodes?

Ans. I should think the relative duration of the contacts and breaks with either instrument, would depend upon the way in which it was adjusted and operated; so that I do not feel that I can give a definite answer to the question.

Cross-Int. 168. Please answer the question with such information as you can derive from Reis's Lecture of 1861, Reis's Circular of 1863, and the Reis-Legat article of 1862?

Ans. I do not see that the statements of these publications enable me to give much more definiteness to my reply than before. I do find however a statement with regard to the operation of the bored block transmitter, the only one described in the Reis Lecture; which shows that with the precise adjustments there assumed, and operated precisely as there described, the break of contact lasts from the beginning of the rarefaction until the middle or nearly the middle of the next condensation, which would give a longer duration to the break, I should think, than would be secured with certain arrangements of the other transmitters; though not longer than might be secured with them.

Cross-Int. 169. Looking now at Reis's cubical box transmitter. What, according to Reis's description of the same, was to be the duration of the separation of the electrodes.

Ans. I do not observe, in either of Reis's circulars to which you refer, any definite statement with regard to the length of time during which the circuit remains open. He simply says, that once in every complete vibration the circuit is opened and again closed. I do not

recall any definite statement as to the duration of the break, in the other publications, beyond the fact that there is to be a distinct and recognizable break at each complete vibration.

Cross-Int. 170. Does Reis use the words "distinct and recognizable"?

Ans. Not so far as I recollect. I used those words simply to indicate what I understood from the statements of contemporary writers, as well as those of Reis himself, to be the minimum duration of the break contemplated by him.

Cross-Int. 171. Reis's exact language describing the "break" as you call it, is as follows, is it not, — "for every full vibration the circuit is once opened and again closed?"

Ans. It is.

Cross-Int. 172. Does that language convey to your mind any idea as to the relative duration of the "break" and contact?

Ans. Considered by itself it gives no evidence as to the relative duration of these, beyond showing that an evident break is to be produced.

Cross-Int. 173. How much of the time of the entire vibration must be covered by the break before this would become what you are pleased to term "an evident break"?

Ans. That I cannot say, numerically.

Cross-Int. 174. Would Reis's condition, that "for every full vibration the circuit is once opened and again closed," be satisfied if the separation between the electrodes should endure for the one one-thousandth part of the entire period of the vibration?

Ans. As I have said already, I cannot give a numerical answer to a question of this nature. I think it is very doubtful whether the condition implied in Reis's language as quoted above, and especially when taken in connection with this and other descriptions of different forms of transmitters of his invention, would be satisfied by the fractional duration of the break that you mention.

Cross-Int. 175. From this I understand you to hold, that if a Reis transmitter of the cubical box form be so constructed and operated that with each vibration of the diaphragm there is an actual separation of the electrodes, but one which endures for only the one one-thousandth of the entire time of the vibration, then such appar-

atus will not embody the condition named in Reis's circular, "for every full vibration the circuit is once opened and again closed." Did you intend to be so understood?

Ans. I think you have quite misun lerstood my meaning. Perhaps I erred in endeavoring to shorten my answer and avoid speaking more specifically. I understand from all that Reis has said with regard to his different forms of instrument, including the present one, that he meant to so break the circuit that the current itself should be absolutely and distinctly broken, and again renewed when the circuit was closed. It was to be open for a sufficient time to produce the well-known magnetic click as the bar was demagnetized and remagnetized. Now it is impossible for me to say broadly that in all cases a period of time equal to one one-thousandth of the duration of a complete vibration will be sufficient to produce this, and I doubt whether it would be, although I know that an excessively minute period of time, a twenty-five thou-andth, or perhaps a fifty thousandth of a second, is sufficient to produce a click in a magneto telephone receiver. But your constant fraction of the period gives a varying absolute direction for the break. If the rate is one hundred vibrations per second, the break would last one one hundred thousandth of a second. If the rate is five hundred vibrations the break will last only one five hundred thousandth of a second. The most that I can really say on this point is, that if it were possible to produce a break of such excessively brief duration as not to allow of sufficient demagnetization and remagnetization of the needle of the receiver to produce the magnetic click, I should not think that it was such a break as Reis described. I have never been able, however, to produce any break of such a short duration that its effect upon a magneto telephone receiver was not evident.

Cross-Int. 176. You seem to think it possible to produce a separation between the electrodes of a telephone of such brief duration that the current itself will not be "absolutely and distinctly broken." Do you, in fact, so hold?"

Ans. I used the term "broken" in respect to the current here, because it was the term which Reis himself had used. The phenomenon which I had in mind was not at all the passage of the current across a gap between the electrodes when they were out of

physical contact with each other, although I see that this might be inferred from my language. I was thinking of the effect of the extra current and other retarding influences in delaying any change in the electrical and magnetic condition of the circuit. I cannot say with any certainty whether it is experimentally possible to produce so brief a break in any and every circuit that the current will not be absolutely and distinctly broken *throughout the whole circuit.* It is easy, however, to do this with certain circuits, as with long telegraph cables,

Cross-Int. 177. I understand you to indicate in your last answer that when contact is broken between the electrodes, even to the extent that the current ceases to pass across the gap thus made, "the extra current and other retarding influences" come into operation and have the effect of "delaying any change in the electrical and magnetic condition of the circuit." Is such the fact?

Ans. These influences always act to delay the rapidity of change in the circuit. Hence, when contact is broken between the electrodes, the current falls off less rapidly than if these retarding influences were not present.

Cross-Int. 178. What are the other "retarding influences" to which you refer, besides the extra current?

Ans. The electrostatic capacity of the line is the chief of these.

Cross-Int. 179. When Reis says that "for every full vibration the circuit is once opened and again closed," what do you understand to be meant by the term "full vibration"?

Ans. I suppose that he means each complete vibration, that is, each complete to-and-fro motion of the diaphragm, corresponding to the fundamental note.

Cross-Int. 180. Then you do not understand that Reis's language contemplates a separation of the electrodes with each change in the motion of the diaphragm corresponding to each or any of the overtones?

Ans. I do not think that I should get that idea from the terms which he uses. His own ideas do not seem to have been at all clear as to the theory of musical tones and the sounds of the voice. His language might, of course, be interpreted to mean one break for each separate vibration corresponding to an overtone, but this is not dis-

tinctly pointed out by him. It seems to me that he had the idea of making the circuit when a condensation was produced, and breaking the circuit when a rarefaction was produced, and hoped that the electrical pulses produced in this way would cause his receiver to vibrate in such a manner as to produce air waves, the curves representing which would be the same as those representing the original air vibrations actuating the transmitter.

Cross-Int. 181. How would you interpret Reis's requirement that the circuit is to be opened and closed once for each full vibration, by reference to the curve *c d* of Mayer's diagram?

Ans. I should, on the whole, interpret his words as meaning that the circuit was to be opened and closed once in the time corresponding to half of the length of the line *c d*.

[*Adjourned.*]

DECEMBER 3, 1886. 11 A. M.

Cross-Int. 182. Do you conceive it possible that with a Reis mechanism, consisting of a cubical box transmitter and a knitting-needle receiver, there may be an actual separation of the electrodes of a transmitter, during so brief a time that by reason of "the extra current and other retarding influences," which you have said operate to delay electrical and magnetic changes in the circuit, no "click" will be given out by the receiver? By "click," I refer to that sound which you have designated by that term in answering Cross-Int. 175.

Ans. If the electrical capacity of the circuit were very great, it is certainly possible. I should suppose that it might be, if the electro-magnetic inertia were exceedingly great. With regard to an ordinary circuit, such as Reis used, I should not think that it would practically be possible to do this, at least repeatedly. I have never seen it done even singly, and the briefest duration of break which I have ever been able to produce, has been evident in its effect.

Cross-Int. 184. How far do you regard this magnetic "click," of which you have spoken in Ans. to Cross-Int. 175, as essential to the operation of a Reis telephone?

Ans. I understand it to be essential to the operation of the instrument according to the method described by Reis and his contemporaries.

Cross-Int. 185. Please explain what this click is.

Ans. When acted upon magnetically by an electric current, the particles of a mass of iron or other magnetic substance are forced to rearrange themselves in some way so that the metal is in a state of what may be called "magnetic strain." The changes in the dimension of the mass, under these circumstances, will produce waves in the surrounding air. If these changes take place suddenly, and with violence, as when the metal is magnetized or demagnetized, a distinct click is produced.

Cross-Int. 186. Assuming Reis's magnetic needle to be at rest, will the first passage of the electric current through the surrounding helix cause the needle to emit this click?

Ans. On closing the circuit at first, the click will be heard.

Cross-Int. 187. That is, the very beginning of the molecular disturbance of the needle will produce a click?

Ans. I cannot say about that. When the circuit is broken and then closed permanently, a click is heard at the moment of closing the circuit. The duration of the click is, I imagine, somewhat longer than the time required by the current to assume its full strength; assuming, as I do, the circuit to be such as used by Reis. Brief as the click is, it must last a sensible time, and the click, as a whole, is not simultaneous with the beginning of the current. Of course, as soon as the particles of the needle begin to move, they begin to produce vibrations in the air, so that, neglecting any lagging that may be due to the magnetic inertia of the needle, I suppose that the beginning of the aerial disturbance which we recognize by the click, is simultaneous with the beginning of the current.

Cross-Int. 188. Perhaps we do not quite understand each other. When Reis's cubical box transmitter is at rest there is a uniform current flowing over the line and through the coils of the needle receiver, is there not?

Ans. There is.

Cross-Int. 189. Assume now an air wave to impinge upon the diaphragm of the transmitter so as to increase the pressure between the electrodes; that will cause an increase in the strength of the current, will it not?

Ans. The strength of the current will undoubtedly increase slightly.

Cross-Int. 190. And proportionately to the increase in pressure?

Ans. Approximately so, at any rate.

Cross-Int. 191. Now, what I wish to know is whether Reis's magnetic needle will give off a click at the very instant when the current, under the hypothesis of the last two or three questions, changes from uniform strength and begins to increase, or, as opposed to this, will the click simply *begin* when this change in the strength of the current begins; its character, as a whole, being determined in a measure by the subsequent changes in the strength of the current?

Ans. I understand that you assume the circuit to remain unbroken. In this case, under ordinary sound waves, the magnetic click proper would hardly be produced, I should say, because the change in the strength of the current, and consequently in the magnetic condition of the needle, is hardly abrupt and great enough for this. There will, however, be a sound produced when the current is periodically varied, and the character of this sound will be determined by the complete series of changes in the strength of the current. The action under these circumstances is substantially identical with that of the carbon microphone.

Cross-Int. 192. By which you mean, I suppose, that there will be a substantial reproduction of the sounds, whatever they may be, which actuate the transmitter?

Ans. The sounds will be substantially reproduced if a proper receiver, like the ordinary magneto receiver, is used. With the knitting-needle receiver in connection with the cubical box transmitter, which you assume to be used, I have never succeeded in understanding speech, except in the imperfect manner which I have already described in this deposition, although I have recognized that the sounds actuating the transmitter were those of the human voice. To this extent, when the instrument is operated as you imagine, there is a reproduction of the sounds actuating the transmitter.

Cross-Int. 193. Now, going back a question or two, do you understand that the magnetic "click," which you say is essential to the operation of Reis's needle telephone, is something different from the sound that is given off by that instrument as you have described its

action under the hypothesis embodied in Cross-Int. 191, in which it was assumed that the electrodes of the transmitter vary their pressure without separating, which condition of things you assert, in answering said question, would "hardly" produce "the magnetic click proper"?

Ans. The term "magnetic click" has always been applied, as I understand it, to the sound which is produced when a mass of iron is suddenly magnetized or demagnetized; and is due to the sudden air waves produced in consequence of the abrupt change of the dimensions of the metal. It is a sound of the same nature as when one opens a penknife. Its character is determined less by the precise way in which the abrupt current varies, than by the mere fact of its abruptness and the physical conditions of the metal itself. The sound produced when the pressure between the electrodes is gradually varied depends rather upon the mode of variation of the pressure. The difference is like the difference in sound produced by the momentary impact of a hammer against a piano string, and the sound produced by the continuous vibration of the piano string itself.

Cross-Int. 194. Do you, then, answer the last question in the affirmative?

Ans. Considering the nature of the sound produced, I should say that they were different; that is, if obliged to answer the question categorically, I should answer it in the affirmative. By this I should mean that it is not by a combination of these clicks that the sound due to microphonic action is produced.

[*Recess*].

Cross-Int. 195. What was there in the object which Reis had in view in constructing his instruments, as set forth in his published accounts of the same, which rendered it necessary for his receiver to give off "magnetic clicks," as distinguished from that other and different class of sounds of which his receiver was capable, and which, as explained by you, were produced by the more gradual changes in the strength of the current?

Ans. Nothing. It was not known, however, in Reis's day, nor previous to the invention of the microphone, that such a gradual

change of current as is produced by that instrument, would give rise to continuous sounds.

Cross-Int. 196. In fact, all the sonorous effects which Reis proposes to produce by his instruments could be produced even in a needle receiver without this magnetic click; could they not?

Ans. Setting aside all questions of loudness, this can be done if a suitable microphone transmitter is employed.

Cross-Int. 197. Please answer the question without making the apparent exception which your last answer seems to make.

Ans. So far as my knowledge goes, using the Reis receiver with a Reis transmitter, it is impossible to produce all the sonorous effects which Reis proposed to produce, either with or without the magnetic click. The magnetic click is not necessary for the reproduction of speech which he proposed, but failed to accomplish.

[*Answer objected to as not responsive, and as making statements which are believed by defendants' counsel not to be in accord with Reis's own statements of what he in fact accomplished.*]

Cross-Int. 198. You say that the magnetic click is not essential to the reproduction of speech. Now what class of sonorous effects *did* Reis undertake to produce which could not be produced except by means of this magnetic click?

Ans. Setting aside all questions of loudness; none.

[*Answer objected to as not responsive*].

Cross-Int. 199. [*Question repeated*].

Ans. None. My reference to the matter of loudness in my last answer was made simply in view of the fact that certain of those sounds which are quite loud, and which have been described as characteristic of the Reis instrument, are not produced except when the circuit is alternately made and broken, so that the magnetic click is produced.

[*All of the foregoing answer, after the first word, is objected to as not called for by the question, and therefore imperttnent*].

Cross-Int. 200. Does Reis make mention of this magnetic click?

Ans. He does, and it is also mentioned in most of the Reis publications. In some cases reference is more especially made, however, to the effect of a large number of rapidly repeated clicks in fusing into a continuous note.

Cross-Int. 201. Did you understand the last question to be limited to Reis's *own* publications?

Ans. I did not know whether it was or was not to be so understood, and therefore shaped my answer so as to reply to the question in either case.

Cross-Int. 202. In which one of Reis's own descriptions do you find mention made of this magnetic click?

Ans. In the description in the Yearly Report of the Physical Society of Frankfort, 1860–61, commonly known as the Reis Lecture; also in Reis's letter to Ladd; also in Reis's descriptive circular of August 9th. The direct reference to the magnetic click in the Reis circular refers to its production when the circuit is made and broken by hand.

Cross-Int. 203. In your Ans. to Int. 7 you have said that the Reis transmitter "is capable of transmitting pitch, and pitch only," Is it because it was capable of transmitting pitch only, that it was incapable (as I understand you to hold) of transmitting speech?

Ans. That would be a sufficient reason. I should rather say, however, that its operation as a circuit-breaker, which adapted it to transmit pitch only, also prevented it from transmitting loudness or quality variations.

Cross-Int. 204. When you speak of a telephone as transmitting loudness, what do you mean?

Ans. I mean variations in loudness, so that the different components of reproduced sounds are brought out with substantially the same relative intensity as in the original sounds.

Cross-Int. 205. Do you hold that a telephone which is capable of reproducing pitch only, is incapable of reproducing speech, but that if, in addition to reproducing pitch, it can reproduce variations in the loudness of the sounds put upon the transmitter, it will then have a capacity of reproducing speech. In other words, is this the substantial difference between a "speaking telephone" and what you conceive the Reis telephone to be, to wit: that the one is capable of reproducing both pitch and variations in loudness of the original sounds, while the other is capable of reproducing pitch only, and not variations in loudness.

Ans. The essential thing in a speaking telephone is that it shall

transmit quality, and quality can be transmitted by an instrument which is capable of transmitting accurately the pitch and relative intensity of the various partial tones constituting speech. The Reis telephone as I understand it, is not a speaking telephone, because it fails to reproduce the pitch and loudness of the various partial tones characterizing speech, and also because of the disturbing effect upon the ear which is produced when the circuit is broken, and which would mask those variations in pitch or loudness, which so far as they exist, are due to microphonic action. I am of course assuming that the instrument is operated as a circuit-breaker, which I understand your question to assume.

Cross-Int. 206. If a Reis telephone, in addition to reproducing pitch, were also to reproduce the variations in loudness of the original sounds, would it be a speaking telephone?

Ans. I should suppose that if any telephone were so operated as to reproduce with fidelity both the pitch and loudness of the various partial tones characterizing articulate speech, it would necessarily transmit quality, and so would be a speaking telephone. If my understanding of the operation of the Reis telephone is correct, however, the supposition made in the question is not possible.

[*Objection is taken to the last sentence of the witness's answer, as being something not called for by the question, and obviously improper.*]

Cross-Int. 207. Does Reis himself say anywhere that his instruments will reproduce pitch only, or is this your conclusion as to the necessary action of the instruments which he describes?

Ans. Reis does not make such a statement. It is my conclusion from the operation of the instrument as he describes it, and from the various statements made with regard to it in the Reis publications as a whole.

Cross-Int. 208. By this expression "Reis publications as a whole," you refer doubtless to the various accounts written by various persons, and which have been put in evidence from time to time in the various Bell suits?

Ans. I do.

Cross-Int. 209. Can you have the quality of a sound recognizably reproduced otherwise than by reproducing approximately its

pitch and the variations of loudness that characterize the partial tones composing such sound?

Ans. To reproduce the same quality at the same pitch, it is necessary substantially to reproduce the pitch and the variations of loudness that characterize the partial tones composing such sound.

Cross-Int. 209. Then if any sound, as for instance that of the letter M, be recognizably reproduced in a telephone, the instrument must have reproduced substantially the variations in loudness that characterize the partial tones of such sound?

Ans. If the letter is recognized simply by the musical elements of its quality, which elements are the only ones that I have been considering in connection with the few questions preceding this, your supposition is correct. In the case of an isolated consonant sound like this, which is more or less explosive in its character, there may perhaps be a considerable departure from exactness in the reproduction of quality without its becoming impossible to recognize the sound. That is, — notwithstanding its distortion it may still be so widely differentiated from other sounds that one knows what it is.

Cross-Int. 210. Do you conceive it possible that any sound, even "an isolated consonant sound," can be recognizably reproduced in a telephone when the pitch only of that sound is reproduced?

Ans. I should say not; though I am not absolutely certain of this. It might be possible for such a consonant sound whose quality is ill-defined, that if the variations in air pressure during the continuance of the sound, or the logographic pressure as it is called, were the same, the consonant might be recognized, even though only the pitch was reproduced. This, however, is so obscure a matter, that what I have said is wholly speculative; but the existence of these peculiar pressure variations and some effects which may come from them, prevent my answering your question as positively as I should like to do.

Cross-Int. 211. So far as your knowledge or belief goes, is it possible that any sound, even an isolated consonant sound, can be recognizably reproduced in a telephone by reproducing the *pitch* only of that sound?

Ans. I have no knowledge that such is the case. With regard to my belief, it certainly seems to me that variations in the loudness

of the fundamental of that sound are necessary to its reproduction. Of course with a consonant sound like this, the mode of beginning and ending that sound is a very important matter, and it is possible that by some such changes as these the sound might be recognized.

[*Adjourned.*]

DECEMBER 4, 1886.

Cross-Int. 212. Then it is your opinion, is it not, that something more than the mere reproduction of pitch is necessary to the recognition of any sound in the telephone?

Ans. It is.

Cross-Int. 213. ' The first diagram in Reis's lecture consists of a curve which, as I understand it, represents the amplitude and the rate, or, in other words, the loudness and pitch of a given sound. Mr. Reis says with reference to this diagram, "Our ear can under no circumstances appreciate more than can be represented by these curves, and this indeed is entirely sufficient to give us a clear perception of any tone or any combination of tones." Do you agree with this statement of Mr. Reis?

Ans. If by "these curves" is meant all curves which can be constructed according to the method that he describes, I agree with the statement.

Cross-Int. 214. What do you understand him to mean by the statement, "Our ear can under no circumstances appreciate more than can be represented by these curves"?

Ans. Reis knew that all the characteristics of sound are due to differences in the condensations and rarefactions of the air conveying the sound waves, and, since these differences can all be represented graphically, he saw and stated, as in your quotation, that it was possible thus to represent all of the variations which affected the ear.

Cross-Int. 215. In other words, is this quotation from Reis a statement, in substance, that all those variations in sound which are appreciable by the human ear, are resolvable, ultimately, into the two elements of loudness and pitch?

Ans. That is not at all the statement which Reis makes. It is rather an inference which we, with our present knowledge, can draw

from the curves, and which we can, therefore, easily interpret his statement as saying. I do not see that there is any reason for believing that Reis consciously held this opinion. I do not think that his views were any more definite than my last answer indicates.

Cross-Int. 216. Do you then think that he did not have in mind the two elements of loudness and of pitch (both of which are represented by the curve of the first diagram of his lecture) when he used the language quoted above?

Ans. My idea is, that in constructing the curves to which Reis refers, he intended to represent the pitch and the loudness of the sound. I think that he saw that, for reasons which I have already stated, it would be possible to represent graphically all possible sound waves. I doubt whether he distinctly formulated to himself the view set forth in Cross-Int. 215. This is, however, simply my inference.

Cross-Int. 217. The passage which I quoted in Cross-Int. 213 follows immediately after the diagram to which I have referred. The language preceding the diagram is as follows, the italics being mine: —

"The office of the auditory nerve is to bring to our consciousness the vibrations of matter which have occurred in a given time, *both as regards number and amplitude*. Here, for the first time, certain combinations receive a name; here, certain vibrations are *tones* or *noises*.

"What our auditory nerve perceives, is then, simply the effect of a force coming within the range of consciousness, and this force can be represented *both as to duration and magnitude* graphically by a curve.

"Let *ab* represent any given time, and the curve above the line condensation (+), the curve below the line rarefaction (—), then any ordinate raised from the end of any abscissa will represent the degree of condensation, at the time represented by its base, in consequence of which the drum of the ear vibrates."

Then follows the diagram referred to, which is immediately succeeded by the words previously quoted, as follows: "Our ear can under no circumstances appreciate more than can be represented by these curves, and this indeed is entirely sufficient to give us a clear perception of any tone or any combination of tones."

Taking this passage as a whole, do you not think that it was Reis's idea that all those air vibrations which produce the sensation of sound are resolvable ultimately into the two elements or characteristics of number or rate and amplitude or force; and that these two characteristics of the air vibrations could be represented graphically by curves, and that the human ear is capable under no circumstances of appreciating more than these two characteristics of sound vibrations?

Ans. As I have said already, I doubt whether Reis distinctly formulated the matter to himself in this manner; but perhaps I am led to this view more by what he does not say than by what he does say, as well as by the state of acoustics at that time. Still, I think that, considering simply what Reis says in those portions of his lecture which you quote, the view taken in your question is a fair one.

Cross-Int. 218. In fact, the curve in the first diagram of Reis's lecture represents only the two characteristics of sound — pitch and loudness?

Ans. On the contrary, it represents quality as well, though Reis makes no allusion to this.

Cross-Int. 219. The only fair inference from this answer is that you intend the Court to understand that quality is a characteristic of sound distinct from pitch and loudness. Is such your real opinion?

Ans. It is. Two sounds may have the same pitch and the same loudness, but have very different qualities.

Cross-Int. 220. Referring now to this first diagram of Reis's lecture, what element in it represents loudness?

Ans. The maximum ordinate.

Cross-Int. 221. And what represents pitch?

Ans. The distance between the two successive crests of the curve, or the distance from *a* to the second point to the right at which the sinuous line intersects the straight line *a b*.

Cross-Int. 222. And what you have called "quality" is represented by what in that curve?

Ans. By the form of the curve; that is, by the sinuous line itself as a whole.

Cross-Int. 223. Does not the length of each of the ordinates of the curve depend upon the intensity of the vibration at the instant of time corresponding to such ordinate?

Ans. As this curve is constructed, it represents simply condensations and rarefactions in the air. Each of the ordinates represents therefore only the excess or diminution in density as compared with the normal density of the air. I do not understand precisely what you mean by "intensity of the vibration at the instant of time corresponding to such ordinate." If you mean velocity of the moving air particle at that instant, I should say that the amount of condensation or rarefaction was dependent upon the relative velocity of neighboring air particles, or of the same particle at successive instants of time.

Cross-Int. 224. Does not what you denominate "the form of the curve" depend upon the *amplitude* of the vibration at each successive instant of the entire time occupied by the vibration which the curve represents?

Ans. The form of the particular curve constructed as explained by Reis, shows simply the variation in density of the sound wave from point to point along its length. The mode in which the density varies, of course depends upon the way in which the particle varies its speed from instant to instant, and hence in one sense depends upon the variation in distance, from instant to instant, of the vibrating air particle from its position of rest which I understand to be the sense in which you use the term "amplitude." Technically, however, the term "amplitude" is applied only to denote the extreme length of the path of the vibrating particle.

Cross-Int. 225. Do you understand that every sound is resolvable theoretically into components, each of which can be represented by a sinusoidal curve?

Ans. Every sound can thus be resolved, except when the sound is a simple one and is represented by a single sinusoidal curve which is incapable of any further resolution. In some cases, as, for example, a noise of brief duration, only a portion of the sinusoidal component curves might exist.

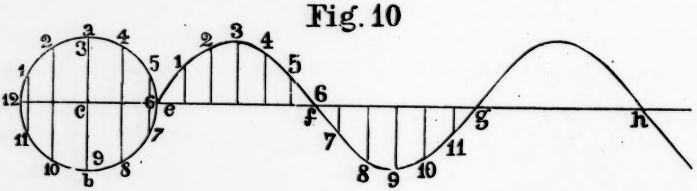
Cross-Int. 226. Will you state briefly what a sinusoidal curve is.

Ans. It is a curve in which, if the abscissa represents an arc, the corresponding ordinate will represent the sine of that arc.

This definition will be made more clear from a consideration of the way in which such a curve may be constructed, and I will, therefore, quote from a foot note on p. 34 of Ellis's Translation of Helmholtz's Sensations of Tone, London, Edition of 1875:

"2. The law of these vibrations may be popularly explained by means of the construction in Fig. 10. Suppose a point to describe the circle of which *c* is the centre, with a uniform velocity, and that an observer stands at a considerable distance in the prolongation of the line *e h*, so that he does not see the surface of the circle, but only its edge, in which case the point will appear merely to move up and down along its diameter *a b*. This up-and-down motion would take place exactly according to the law of pendular vibration. To represent this motion graphically, by means of a curve, divide the length *e g*, supposed to correspond to the time of a single period, into as many (here 12) equal parts as the circumference of the circle, and draw the perpendiculars 1, 2, 3, etc., on the dividing points of the line *e g*, in order, equal in length to and in the same direction with, those drawn in the circle from the corresponding points 1, 2, 3, etc. In this way we obtain the curve drawn in Fig. 10, which agrees in form with that drawn by the tuning fork, Fig. 6, p. 30, but is of a larger size.

Fig. 10



Mathematically expressed, the distance of the vibrating point from its mean position, at any time, is equal to the sine of an arc proportional to the corresponding time, and hence the form of a simple vibration is also called the *curve of sines*."

The curve generated in this manner is a sinusoid.

Cross-Int. 227. The needle receiver of the Reis telephone is an electro-magnetic instrument, is it not?

Ans. It is.

Cross-Int. 228. If a diaphragm carrying an armature of inductive metal were presented to the pole of Reis's needle receiver, would the instrument then become substantially the same, so far as regards the general principle of its construction, as the receiver shown in Fig. 7 of Bell's first patent?

Ans. I should think that it would.

Cross-Int. 229. Is it your idea that with a circuit-breaking transmitter in which the electrodes separate with each full vibration, the receiving magnet returns at each vibration substantially to a state of magnetic rest? Assume further that the vibrations of the transmitter are such as would be produced by the sounds of the human voice in ordinary speech.

Ans. I think that it does. By "a state of magnetic rest," I understand a condition in which the magnetism is not changing from instant to instant.

Cross-Int. 230. Is it your idea that when the electrodes of a circuit-breaking telephone separate when the instrument is acted on by the sounds of the human voice, the magnet of the receiver returns substantially to its normal magnetic or molecular condition? By "normal" condition, I mean of course its condition at the time when the transmitter is at rest.

Ans. Certainly not. When the transmitter is at rest the current is flowing and the needle is strongly magnetized. Immediately upon breaking the circuit the magnetism falls off abruptly.

Cross-Int. 231. Is it your idea that with each vibration of a circuit-breaking transmitter, assuming the electrodes to separate with each full vibration of the diaphragm, the receiving magnet is entirely demagnetized or substantially so?

Ans. Not entirely demagnetized, unless the iron is exceedingly soft, or the break somewhat prolonged. The magnetism always however falls off very abruptly, and to a notable extent.

Cross-Int. 232. My object was not to learn whether the magnetism falls off "abruptly," but to what extent the demagnetization will be carried, assuming the breaks to occur with a frequency corresponding to the number of full vibrations characterizing human speech.

Ans. I cannot state by what percentage the magnetism falls off under these circumstances, because it depends upon the duration of

the breaks and upon the hardness of the needle, as well as upon its size; but if the iron is soft and the needle small, the magnetism falls off to a small fraction of its maximum value with very great rapidity.

Cross-Int. 233. It would appear, then, that the extent of the demagnetization of the receiving magnet depends in part upon the duration of the break; will the loudness of the click consequent upon the break also depend, for any given instrument and any given strength of current, upon the duration of the break?

Ans. The loudness of the click I think depends more upon the suddenness with which the break is made, and the consequent abruptness with which the magnetism falls off, than upon the duration of the break. I am not prepared to say, however, that comparing excessively brief breaks with longer ones, the loudness of the click is entirely independent of the duration of the break.

Cross-Int. 234. I judge by this that in your opinion the duration of the break is a material factor, though not the most material one, in determining the loudness of the reproduced sound?

Ans. I do not think that moderate or even very considerable differences in the duration of the break materially affect the loudness of the click. That is, considering simply the matter of duration of break entirely apart from variations in its abruptness, I do not believe that there would be any considerable difference in the loudness of the click whether the break lasted say $\frac{1}{500}$ or $\frac{1}{1000}$ of a second. Very likely there would be a considerable difference if the breaks considered were $\frac{1}{500}$ and $\frac{1}{5000000}$ of a second, respectively, in duration.

Cross-Int. 235. Take such breaks as would occur if the circuit-breaking instrument that we are talking about were actuated by the tones of the human voice in ordinary speech. Under these circumstances would the loudness of the click of the receiving magnet be dependent upon the duration of the breaks?

Ans. Under these circumstances I should think that the differences due to greater or less abruptness in the break, according as the vibrations were more or less rapid, would almost entirely mask any effects which might otherwise be produced by simple differences in the duration of the breaks. Setting this matter of abruptness aside, however, I do not imagine that in the ordinary operation of

such a circuit-breaking transmitter there would be any material differences in loudness, coming simply from such differences in duration of the breaks that would occur.

Cross-Int. 236. What, in your opinion, would be "material" differences in loudness?

Ans. Differences which would give an evident difference in the loudness of the note produced when the clicks succeed each other so rapidly as to give a continuous sound, or differences which seem considerable to the ear when only a single click is produced.

[*Adjourned.*]

DECEMBER 6, 1886, 2.15 P. M.

Cross-Int. 237. If it should appear that in the operation of the original Reis instruments there were, in fact, material variations in the loudness of the sound produced by the receiver, to what would you attribute such phenomenon if not to variations in duration of the break of the circuit?

Ans. I should be inclined to attribute them to the differences in the rapidity with which the break was made. That is, to differences in the actual velocity with which the style forming the anvil electrode was moving when the break occurred.

Cross-Int. 238. And this in turn, I suppose, would depend upon the energy of movement of the diaphragm, and ultimately upon the strength of the sound wave?

Ans. It would depend upon the strength of the sound waves, that is, upon the amplitude of the vibrations of the diaphragm, and also upon the pitch of the sound, and upon the quality of the sound as well.

Cross-Int. 239. Then, as I understand you, whatever variations in loudness are observable in sounds reproduced in a Reis telephone operating as Reis intended his telephone to operate, are dependent ultimately, for any given pitch, upon the amplitude of the vibration of the transmitting diaphragm and the quality of the original sound?

Ans. I suppose that they are dependent upon these, but not, however, proportional to them.

Cross-Int. 240. Do you then disagree with Reis in his statement of the matter, who, as I understand it, asserts, first, that the inten-

sity of the reproduced tone is proportional to that of the original one, and who also asserts that these variations in intensity or loudness are dependent upon the duration of what you call breaks?

I quote the particular portion of Reis's lecture to which I allude which is as follows:—

"The intensity also of this tone [the sound given off by the receiver] is porportional to that of the original one, for in proportion as this is more intense, the motions of the membrane are greater; the motions of the hammer, also, and finally, the time during which the circuit remains open, is greater; and consequently, up to a certain limit, the motions of the atoms in the reproducing wire are greater, we perceiving them as greater vibrations, in just the same way as we would have perceived the original sound wave."

Ans. I do not think that Reis is correct in the statements which you quote.

Cross-Int. 241. How rapidly is it necessary that separate and distinct sounds shall succeed each other in order to produce upon the human ear the sensation of a continuous sound?

Ans. That varies a good deal with the nature and violence of the impulse. About sixteen double vibrations a second is the limit usually assigned.

Cross-Int. 242. Given a series of separate and distinct sounds of the same pitch succeeding each other with such rapidity as to produce upon the ear the sense of a continuous sound, would variations in the loudness of such separate sounds be manifest in the effect produced upon the ear; and, if so, in what way?

Ans. You have asked a question which involves one of the most perplexing and disputed points in modern acoustics. Undoubtedly such periodic variations in the strength of the impulse will produce variations in the resulting continuous sound. The nature of these variations would vary considerably, according to the nature of the separate impulses, and the mode of variation in their intensity.

Cross-Int. 243. How many vibrations per second will the diaphragm of a telephone transmitter make when subjected to the sound of the human voice in ordinary speech?

Ans. That depends of course upon the pitch of the voice. Perhaps about two hundred vibrations per second is a fair number to mention.

Cross-Int. 244. This would be the case with a Reis transmitter as well as with a Blake transmitter?

Ans. It will.

Cross-Int. 245. What is the necessary minimum range of movement of the diaphragm of a telephone transmitter when engaged in transmitting speech?

Ans. I cannot say; except that it may be very small.

Cross-Int. 246. What do you mean by "very small"?

Ans. My idea is quite as indefinite as my expression, so that I do not believe that without experiment I can answer the question.

Cross-Int. 247. Do you conceive it possible to transmit speech with a microphone transmitter whose diaphragm is made of iron one fourth of an inch in thickness?

Ans. I have never tried the experiment; but I think it quite possible that speech could be thus transmitted.

Cross-Int. 248. The air particles when performing sound vibrations move through a range of, approximately, the one ten millionth of a centimetre?

Ans. That is a result reached by Rayleigh who is one of the highest authorities on sound; and is the best information we have on the subject.

Cross-Int. 249. What fraction of an inch is this?

Ans. A centimetre is about ten twenty-fifths of an inch; so that the magnitude measured by Rayleigh is about one twenty-five millionth of an inch.

Cross-Int. 250. Can you give the Court any idea of the amount of deflection that would be produced in a telephonic diaphragm made of iron one quarter of an inch in thickness by the impingement upon it of air particles vibrating through a range of one twenty-five millionth of an inch?

Ans. No definite idea, in the absence of any experimental measurement. The setting up of such vibrations however is not so startling a matter as might be inferred from the question, since the number of these molecules is almost innumerably great, and the diaphragm is set into motion by sympathatic vibration, in which a small impulse frequently repeated is capable of producing marked effects.

Cross-Int. 251. What is the size and weight of the air particle of which you discoursed in your direct testimony?

Ans. I do not know.

Cross-Int. 252. In what sense have you used the term "air particle" in your testimony?

Ans. As meaning simply an exceedingly small mass of air.

Cross-Int. 253. Define "exceedingly small" as you use it.

Ans. I have not attached any definite numerical significance to the term, nor is it customary or necessary to do this in acoustic investigations. It is perhaps a quantity of the same order of magnitude as the amplitude of its vibration.

Cross-Int. 254. In the case of an ordinary telephone transmitter, such as the Blake, what is the extent of the vibration of the diaphragm, when acted upon solely by the air particles moving through their range of one twenty-five millionth of an inch?

Ans. Professor E. W. Blake's curves referred to in my answer to Int. 12, give a magnification to the vibrations of something over one hundred. That would give for certain of the moderate vibrations of the diaphragm an amplitude of about one eight hundredth of an inch. I cannot say what the length of the path of the vibrating air particles was in this case, since the vibrations were produced by the human voice, instead of by a whistle as in Rayleigh's experiments; but the order of magnitude in the two cases is of course the same.

Cross-Int. 255. Did Blake make his experiments with a contact transmitter or a magneto instrument?

Ans. He used a diaphragm only, which I believe was the diaphragm of a magneto instrument.

Cross-Int. 256. Then, as I understand you, the vibrations, which Blake's diagrams constitute a record, were not the vibrations of a diaphragm which was at the time actually transmitting, or employed as part of an apparatus which as a whole was transmitting, speech?

Ans. They were not.

Cross-Int. 257. Do you know with what tone of voice Blake spoke to his diaphragm?

Ans. I do not recollect as to this, but probably in a loud tone.

Cross-Int. 258. Why "probably in a loud tone?"

Ans. Because if one wished to get clearly marked effects with an apparatus like that of Blake's he would naturally use a loud tone.

Cross-Int. 259. Louder than in talking to an ordinary Blake transmitter?

Ans. Very much louder. If you desire, I will refer to the original article by Prof. Blake, who probably states the matter with more definiteness than I recollect it.

[*The witness is requested to do so and report at the next session.*]

Cross-Int. 260. Do you know what was the position of Blake's mouth in relation to the diaphragm at the time of performing the experiments?

Ans. I suppose that it was very near to the diaphragm.

Cross-Int. 261. So near that the diaphragm may have been affected not only by the action of the air particles due to their infinitesimally small sound vibrations, but also by the impact of a mass of air forced against it by the muscular action of the organs of speech?

Ans. Undoubtedly. This always occurs in telephonic transmission. There are some apparent traces of itsh own in Prof. Blake's curves.

Cross-Int. 262. Blake, then, was not endeavoring to obtain a record of the movement of the diaphragm of a telephone when employed in the transmission of speech?

Ans. As I understand the matter, he was endeavoring to ascertain the manner in which a telephone diaphragm vibrated under those circumstances. He found it more convenient to experiment with the diaphragm in the absence of the other portions of the apparatus, and assumed, undoubtedly with correctness, that the mode and the extent of the vibration of the diaphragm were substantially the same with the disk as he employed it, as in the transmitting telephone itself when transmitting speech.

Cross-Int. 263. Had he, however, the right to assume that "the mode and the *extent*" of the vibration of the diaphragm would be the same when he spoke to it "very much louder" than it would be spoken to when employed in the actual transmission of speech?

Ans. He did not assume this. Of course if he used a louder

tone of voice in his experiments than is used in the transmission of speech, the vibrations of the diaphragm will have a greater amplitude, but with the magneto telephone whose diaphragm, if I recollect rightly, Prof. Blake used, it was not infrequent to employ a very loud tone of voice, much louder than is usually employed with such a microphone transmitter as the Blake.

Cross-Int. 264. Then the Blake diagrams are not a record of the extent or range of the vibration of the diaphragm of a contact transmitter when transmitting speech, which was the thing inquired about in Cross-Int. 254?

Ans. Not of a Blake transmitter as it is ordinarily adjusted, since that is too sensitive to allow of the use of a very loud tone of voice. I mentioned these results of Blake's in order to give an approximately correct numerical answer to the question asked, and the only other data which I had seen were not at hand. Perhaps, for tones of average intensity, three quarters or one half of the amount that I mentioned would be a suitable estimate for the contact transmitter as ordinarily employed, but this is simply an estimate.

[*Adjourned.*]

DECEMBER 7, 11 A. M.

Cross-Int. 265. In your direct testimony, in answer to Int 49, you spoke of certain experiments with a Blake transmitter, in which you clamped the electrodes together. When speech was transmitted with the electrodes in this condition the result depended upon the movement of the electrodes relatively to each other, did it not?

Ans. It did.

Cross-Int. 266. Now, can you give the Court any idea as to the maximum movement of the diaphragm relatively to the anvil electrode when the parts were thus clamped?

Ans. I cannot say definitely, as I did not attempt to measure it.

Cross-Int. 267. What is the best estimate that you can give?

Ans. An estimate would be only a guess, as I do not recall any experiments of my own which would enable me to answer the question numerically; and I do not know of any experiments by others bearing upon the point.

Cross-Int. 268. Take an ordinary Blake transmitter, do you

know what is the maximum relative movement of the two electrodes when the instrument is transmitting speech?

Ans. I do not.

Cross-Int. 269. Do you know of any method of measuring the relative movement of these parts?

Ans. There are several methods which could be employed for this purpose, and which have been used for the solution of very similar problems. One of the methods that I refer to is known as the stroboscopic method of observing moving bodies. Another method, involving the use of the microscope, I have referred to in my answer to Int. 48.

Cross-Int. 270. Can you state the maximum relative movement of the electrodes of a Blake transmitter away from each other which can occur without the electrodes actually separating?

Ans. I cannot.

Cross-Int. 271. Would they separate if the movement were as much as the one-thousandth of an inch?

Ans. I think it probable that they would, but am not absolutely certain that this would necessarily be the case.

Cross-Int. 272. You have frequently used a magneto transmitter; that is, a transmitter operating by variations in the electro-motive force?

Ans. I have.

Cross-Int. 273. Have you ever found that the reproduction of speech by means of such an instrument was materially interfered with if the mouth of the speaker was placed too close to the diaphragm?

Ans. I never found any special trouble from this, although I know that the best results are obtained with such an instrument by speaking in a full, clear tone of voice rather than by shouting. Also, one must not muffle his voice by pressing the mouthpiece of the instrument too closely against the lips.

Cross-Int. 274. When you transmitted speech with a Reis telephone, how did you speak to the instrument?

Ans. I have never been able to transmit speech by the Reis transmitter, even though using a Bell magneto as a receiver, except by speaking very gently to the transmitter so as not to cause it to act as a circuit-breaker.

Cross-Int. 275. Could you in your experiments tell, by watching the electrodes, whether they broke contact?

Ans. I could, by watching the electrodes, tell whether they broke contact habitually or not.

Cross-Int. 276. Did you ever experiment with the Reis transmitter by speaking down upon the diaphragm instead of into the mouthpiece?

Ans. I have.

Cross-Int. 277. With what result, as compared with that obtained when you spoke into the mouthpiece?

Ans. I do not distinctly recollect any great difference. My impression is that it was more difficult to keep from breaking the circuit when the mouthpiece was used than when it was not used, but I am not certain how much my impression is due to the direct results of experiment, how much to inference, and how much to what I have seen others do or read of their doing.

Cross-Int. 278. When you spoke "very gently" to the Reis instrument, how far away could your words have been heard by others in the same room?

Ans. I cannot say. That would of course depend a good deal on the size of the room, but I should think they might have been understood, in a quiet room, ten or twelve feet away, or, very likely, considerably more.

Cross-Int. 279. Have you ever experimented with a Reis telephone in which one of the electrodes was carbon?

[*Objected to as incompetent and inadmissible, on the ground that there is no evidence that a Reis telephone ever had a carbon electrode, and on the further ground, that if a carbon electrode were introduced into such an apparatus, it would cease to be a Reis telephone.*]

Ans. I have not.

Cross-Int. 280. What, in your opinion, would be the effect upon the capacity of a Reis telephone of substituting carbon electrodes for those shown by Reis?

Ans. Inasmuch as carbon is one of the worst substances known for use in a circuit-breaker, while platinum is perhaps the best; the effect of such substitution would doubtless be to diminish the capacity of the Reis transmitter to operate in the manner described by Reis.

Cross-Int. 281. Do you then think that if the triangular anvil electrode of Reis's cubical box transmitter were made of carbon, its weight remaining unchanged, the instrument would thereby be rendered better adapted for the transmission of speech?

Ans. I think that it would.

Cross-Int. 282. Why?

Ans. Because a microphone in which one of the electrodes is of carbon is more efficient than a microphone in which both electrodes are of platinum.

[*Recess.*]

Cross-Int. 283. Please explain why.

Ans. Because with the substance carbon there is a greater variation of resistance for a given variation in pressure, the normal pressure being the same, than with platinum. Also the simple proportionality between the variation in resistance and the variation in pressure extends through a greater range with carbon than with platinum.

Cross-Int. 284. Is it known why a given variation of pressure will produce a greater variation of resistance in the case of carbon than in the case of platinum?

Ans. Not certainly. The subject has not been investigated to any considerable extent.

Cross-Int. 285. Would it in your opinion be a material improvement of the Reis telephone, I mean would it materially increase its capacity of transmitting speech, if, in addition to substituting carbon for one of the platinum electrodes, a metallic diaphragm were to be substituted for that shown by Reis?

Ans. Undoubtedly both of these departures from the construction of the transmitter as described by Reis, better adapt it to employ the mode of transmitting speech invented by Mr. Bell.

Cross-Int. 286. Would the Reis transmitter, altered as indicated in the last question, make a practical instrument for transmitting speech?

Ans. I think it probable that you could transmit speech by means of it experimentally, but doubt if it could be used commercially.

Cross-Int. 287. If there were no better telephone in existence do you think that it could not be used commercially?

Ans. Perhaps it might for some special purposes, and to a limited extent.

Cross-Int. 288. Would it not be as good for commercial purposes as the instrument shown in Fig. 7 of Bell's first patent, if the latter were made of the proportions indicated in said figure, and with a membrane diaphragm?

Ans. Very likely it would be if we were limited to the use of the membrane diaphragm in the Bell instrument. It would not be, however, I think, if we made the same change in the diaphragm of the Bell instrument which you suggest in that of the Reis instrument. I am not at all certain that it would be in any event.

[*All of the foregoing answer, except the first sentence, is objected to as relating to a matter not inquired about.*]

Cross-Int. 289. In practice, which has been found the most serviceable class of telephones, the magneto instrument which depends on varying the electro-motive force, being the instrument shown in Fig. 7 of Bell's first patent, or the contact transmitter which operates by varying the relation of the electrodes through which the current passes?

Ans. As a transmitter, the microphone, when employed, as is customary, with an induction coil, has been found to produce louder effects, and is in that sense more efficient than the magneto-transmitter.

Cross-Int. 290. Is the microphone instrument the one that is generally used commercially?

Int. It is.

Cross-Int. 291. According to *your* idea the microphone transmitter was invented subsequent to Mr. Bell's invention as set forth in his first patent?

Ans. Undoubtedly.

Cross-Int. 292. Did the adoption of the microphone transmitter constitute a notable advance in the art of telephony?

Ans. It did.

Cross-Int. 293. Did the use of the induction coil in connection

with the microphone transmitter constitute a notable advance in the art?

Ans. It did.

Cross-Int. 294. Can you have a microphone without *carbon* electrodes?

Ans. You can.

Cross-Int. 295. Did the use of carbon electrodes constitute a marked improvement in the art of telephony?

Ans. The first microphones which were employed, otherwise than experimentally, used carbon electrodes. If metallic electrodes had previously been used in microphonic telephone transmitters, it would have been a marked improvement to replace them by carbon electrodes. Of course it is not necessary, nor indeed desirable, to have both electrodes of carbon.

Cross-Int. 296. Referring to your experiments with the Blake instruments as described in your answer to Int. 49, do you understand that the presence of the sparks was proof that the circuit was broken?

Ans. I do.

Cross-Int. 297. Is there no other theory on which the sparks could be accounted for?

Ans. I do not know how else to account for them under the circumstances of those experiments.

Cross-Int. 298. Then if a contact transmitter were giving off sparks continuously during the vibration of the diaphragm under the action of sound waves, this would be proof to your mind that the circuit was being continuously interrupted?

Ans. I should conclude that it was interrupted at the instant that each spark occurred. I assume, of course, that there are actual sparks, and not a mere bringing an electrode to slight incandescence, without parting contact, which I have known to be mistaken for a spark.

Cross-Int. 299. Wherein, otherwise than in degree, does an actual spark differ from this incandescence of the electrodes?

Ans. In the incandescence of the electrodes the material of the solid electrode itself, through which the current is passing, is rendered hot by the direct passage of the current. In the case of the

spark, the incandescent matter is volatilized and torn violently away from the electrodes themselves.

Cross-Int. 300. It seems then to be a matter of degree dependent upon the extent to which the electrodes move in opposite directions?

Ans. The spark will not be produced unless the electrodes part contact, It is different, however, in the phenomena accompanying it, and in its laws of action, from the incandescence of the solid electrodes when a strong current passes through them.

Cross-Int. 301. Can you always distinguish by the sight between sparks arising from excessively minute breaks of contact of the electrodes, and the incandescence of the electrodes as they approach the point of separation?

Ans. Their appearance is quite different, and while I will not say that in every particular case the unaided eye would so certainly distinguish them that it could never be mistaken, yet there is in general no difficulty, and there are various appliances which would enable us to determine, if we were otherwise in doubt. Thus by the microscope, the revolving mirror, or the stroboscope, we might solve the question.

Cross-Int. 302. Might you not have a spark produced without an actual break of contact between the electrodes, as, for instance, if you assume the number of points of normal contact between the electrodes to be one thousand, and these are suddenly reduced, by the vibration of the parts, to two?

Ans. The production of sparks has universally been recognized as occurring only on a separation of the electrodes. I do not think that a spark would be produced even in the extreme case which you mention.

Cross-Int. 303, I understand you to say, in answer to Cross-Int. 168, that in Reis's bored block transmitter "the break of contact lasts from the beginning of the rarefaction until the middle, or nearly the middle, of the next condensation." Why do you say until "nearly the *middle*" of the next condensation?

Ans. I assumed in that reply that the wire *d* came in contact with the strip of metal at about the middle of the condensation, and that

d was pushed back a slight distance; that soon after the rarefaction occurred contact was broken until at the next condensation contact was made at or about the middle point. If I were to substitute *about* for *nearly* in my answer to Cross-Int. 168, the idea which I had in mind would be more clearly expressed. I think, however, on further consideration of the matter, that my assumption is a somewhat arbitrary one, and that the break was probably longer than I inferred.

Cross-Int. 304. Why did you assume in answering Cross-Int. 168 that the wire *d* came in contact with the strip of metal constituting the hammer electrode "at *about the middle* of the condensation"?

Ans. I suppose that when I was asked the question, I in some way inferred this from the statement of Reis. On reading it over again I see that his words do not imply this, and I am at a loss to understand my precise train of thought when that answer was given. What Reis really indicates is, that when the rarefication occurs the current is broken and remains so until the next condensation again brings the electrodes into contact. This, I should think, would indicate a greater duration of the break than I had in mind when I answered Cross-Int. 168.

Reis's words are as follows: —

"At the first condensation the hammer-like wire *d* is pushed back; at the rarefaction it cannot follow the retreating membrane, and the current traversing the strips remains broken until the membrane, forced by a new condensation, again presses the strip (proceeding from *p*) against *d*. In this way each sound wave causes a breaking and a closing of the current."

Cross-Int. 305. Do you understand that this language of Reis when interpreted in the light of the context, and also in the light of the report of Reis's lecture, as published in the *Frankfurter Conversationsblatt* of Nov. 29, 1861 (in which the strip which carries the wire *d* is spoken of as an "elastic strip"), implies that when the wire *d* is once pushed back it remains absolutely stationary, or only that it cannot follow the retreating membrane in the sense of keeping up with it?

Ans. Reis does not say that the wire *d* is elastic, and, as far as

his language shows, one would infer the contrary. The statement regarding the operation of the instrument in the *Frankfurter Conversationsblatt* is as follows:—"As soon then as the sound waves set the membrane in vibration, the elastic strip of metal fastened to the same will make the same vibrations, will alternately rise and fall, thereby *touching* the other elastic strip, and so making and breaking the current."

The italics are mine.

I do not see that in the last statement any operation of the strip forming the anvil electrode, which is dependent upon elasticity is indicated. It seems to state only that the strip is touched at intervals, which gives the same idea as that derived from the statement of Reis which I have quoted. I should infer from the descriptions, that the wire *d* could follow only very slightly the retreating membrane, so that the contact was broken except during a comparatively small fraction of the vibration.

Cross-Int. 306. Then it is your belief, is it, that in Reis's bored block transmitter the elasticity of the strip carrying the wire *d* (which characteristic of the strip seems to have been specially referred to by the reporter of Reis's lecture, when he described it as an *elastic* strip) performed no function whatever?

Ans. My belief is that if the instrument operated in the manner described by Reis, no material effect was produced in virtue of the elasticity of the strip. That is, if a rigid inelastic strip had been used, the function of the strip as the anvil electrode of a circuit-breaker would still have been performed. The use of having it elastic, as far as I see, would be to prevent its being bent if pushed back by the vibrating membrane, in which case none but strong vibrations of the membrane would operate to close the circuit.

Cross-Int. 307. Was it not absolutely essential, even to Reis's method of operating the instrument, as you understand the same, that the wire *d* be mounted upon a strip of such elasticity that if pushed back by a "strong vibration" of the diaphragm, it would, by virtue of its elasticity, so far return towards its original position that the wire *d* would not fail to come in contact with the diaphragm on the next succeeding vibration, even though this were a weaker vibration, and therefore of less amplitude?

Ans. Doubtless; but the wire *d* might be mounted upon such a

heavy and so rigid a strip that it would not sensibly be pushed back by the strongest vibration employed, in which case the instrument would work perfectly well. Every strip, however, will practically possess a certain amount of elasticity, and would probably answer the requirements of your question.

[*All of the foregoing answer, after the first word, objected to as introducing into the discussion a hypothesis not referred to in the question, and one which is directly at variance with Reis's own instructions, in that he requires the strip to be such that it can be pushed back by the action of the diaphragm.*]

[*Adjourned*]

DECEMBER 9, 11 A. M.

Cross-Int. 308. Referring to your description of the electric spark in ans. to Cross-Int. 299, is it your idea that the current is actually passing between the electrodes during the time of the spark?

Ans. I understand that the spark is produced at the moment of rupture of contact. At that instant the current is broken and dies away with exceedingly great rapidity. The actual duration of the spark, that is, the period during which the particles whose incandescence gives the light continue to glow, is also excessively brief. Which is the longer of the two depends upon various conditions of the current and the circuit.

Cross-Int. 309. Can there be a spark without an actual passage of current between the electrodes after they separate?

Ans. There can certainly be a spark such that we can detect no passage of the current after the electrodes separate. Whether there is any passage of current so feeble or so brief in duration that we can not detect it though it nevertheless exists, I cannot say. It is is possible that when the electrodes are out of physical contact by an excessively slight distance, some current may yet pass.

Cross-Int. 310. Is not the spark the result of the action of the current upon the electrodes consequent on their separation?

Ans. In one sense it is. The spark, however, is analogous rather to the disruptive discharge, as it is called, such as you get when an ordinary Leyden jar is discharged. The character and laws of the spark discharge are quite different from those of the current.

Cross-Int. 311. Probably you do not conceive it possible for two electrodes to be separated just enough to produce a spark, and then to be immediately reunited so as to permit the current to resume its normal flow, without a complete and absolute cessation of the current before such reunion?

Ans. I have no difficulty in imagining such an action as a mental conception; but I have never seen or read of any apparatus in which this was done, and I think it would be extremely difficult to construct an apparatus which would do it unquestionably and successfully.

Cross-Int. 312. To your mind the development of a single spark between the electrodes of a contact transmitter is evidence that the current is absolutely broken, is it not?

Ans. My belief is that the current does not pass between the electrodes when the spark is produced. Of course I cannot say that absolutely no current passes, but my belief is that no measureable quantity passes.

Cross-Int. 313. Would the practical effect be the same as if absolutely no current passed?

Ans. That is my belief.

Cross-Int. 314. You are well aware of the fact that a voltaic current, and also an induced current will, under some circumstances, continue to pass between two electrodes which are not in contact, are you not?

Ans. I am; as for example with the electric arc of the arc light.

Cross-Int. 315. In the arc light how far may the electrodes separate without interrupting the current?

Ans. In some case, up to four or five inches, or even considerably more.

Cross-Int. 316. If the electrodes of the arc light can be separated a distance of four or five inches without interrupting the flow of the current, is it not conceivable that the electrodes of a contact telephone transmitter may be separated at least to an exceedingly minute extent, without breaking the current?

Ans. It is perfectly conceivable as a mental abstraction, but I never have seen or heard of its being done. The reasoning from

the electric arc to the electric spark, and inferring that because under certain conditions with a strong current one can produce a considerable separation of the electrodes without breaking the current, he can, therefore, under quite different conditions and with a weak current produce a slight separation of the electrodes without breaking the current, is fallacious.

Cross-Int. 317. Then you do not deny that the electrodes of a contact transmitter may be separated, at least to an exceedingly minute extent, without interrupting the flow of the current?

Ans I do not deny the possibility absolutely and without limitation.

Cross-Int. 318. Do you know what is the electro-motive force of the ordinary telephonic current?

Ans. The total electro-motive force in the circuit is somewhere about one and five tenths volts.

Cross-Int. 319. In Ans. to Cross-Int. 302, you express the opinion that if the contact area between two electrodes of a transmitter were to be suddenly reduced in the ratio of one thousand to two, by the vibration of the parts, no spark would be produced. I now ask whether the effect upon the transmission of speech would be practically the same as if a spark were produced; or, in other words, the same as if the electrodes were wholly separated, and the current absolutely interrupted?

Ans. In my opinion it would not.

Cross-Int. 320. Speech, you think, would still be transmitted, notwithstanding such near approach to what you call a break?

Ans. I do; assuming of course that all extraneous disturbances are avoided.

Cross-Int. 321. You have, in your testimony, made some references to "logographic" action in a telephone. Please state briefly what this is.

Ans. It is the bulging in of the diaphragm due to comparatively slow variations in the pressure of the air against the diaphragm during the production of a sound, as distinguished from the very rapid vibrations of the sound waves.

Cross-Int. 322. May this logographic action become such under any circumstances as to mask the phenomena connected with and

growing out of the movements of the diaphragm due to the very rapid vibrations of the sound waves in the transmission of speech?

Ans. It might under certain circumstances.

Cross-Int. 323. With a magneto telephone as well as a microphone instrument?

Ans. That might be the case, although such action would be much less likely to occur.

Cross-Int. 324. Will you furnish a cut of the Blake transmitter with which you performed the experiments described in Ans. to Int. 49?

Ans. I will do so; and hereby produce it.

[*It is agreed that the cut be introduced into the printed record in connection with Ans. to Int.* 49.]

Cross-Int. 325. In Ans. to Cross-Int. 243 you have mentioned two hundred as being approximately the number of vibrations per second of a telephone diaphragm actuated by the human voice. That, I suppose, is the number representing the *fundamental* of the human voice?

Ans. That is the case at the assumed pitch.

[*Recess.*]

Cross-Int. 326. What is the number of overtones corresponding to this number of the fundamental vibration?

Ans. The vibrations of the overtones would be equal to the number of the fundamental vibrations multiplied by two, three, four, five, and so on. That is, to four hundred, six hundred, eight hundred, one thousand, etc., vibrations.

Cross-Int. 327. Then, in the ordinary sounds of the human voice, the vibrations corresponding to the overtones greatly exceed in number those corresponding to the fundamentals?

Ans. They do.

Cross-Int. 328. Numbering, in the case of most sounds, some thousands per second?

Ans. I should think some of the overtones would usually be at least as high as this.

Cross-Int. 329. Now, can you state how many of these vibrations, or of the partial tones resulting therefrom, can be obliterated

in the case of human speech without rendering the speech unintelligible?

Ans. I cannot definitely. Doubtless, some of the overtones may be omitted without causing the speech to become unintelligible.

Cross-Int. 330. In the last paragraph of your answer to Int. 48 you say, italics mine:—

"I am sure that it is impossible for any instrument to be so ideally perfect as to reproduce the sound with absolute and mathematical fidelity, and therefore I consider that the method" [that described in the fifth claim of Mr. Bell's patent, No 174,465] "is substantially employed whenever articulate sounds which are recognizably the same as those spoken into the transmitter are produced at the receiver by the employment of current variations (caused by the voice) which are recognizably similar to the sound waves, and which, *though to some extent misshapen, deformed, injured, disturbed, weakened or lost*, yet produce the same result by reason of so much of the true form as is created and preserved; because in such case the speech is transmitted by reason of the articulating undulations, and in spite of the imperfections thereof."

Do you then hold that it is the *amount* of the deformation or loss which the form of the vibration undergoes in a telephonic apparatus, rather than the fact that there is *some* deformation or loss, that proves destructive to the reproduction of speech, and thus puts any given apparatus outside the fifth claim of Bell's first patent?

Ans. I understand that an apparatus, to embody the invention set forth in that claim, must secure whatever transmission of speech is secured, by the production and utilization of electrical undulations similar in form to the air waves. Even though this simliarity is imperfect I should consider the method to be employed when speech is transmitted in virtue of the similarity that exists, rather than in virtue of such dissimilarity as exists. Doubtless it is the amount of the deformation or loss, rather than the fact that there is *some* deformation or loss, which proves destructive to the reproduction of speech.

Cross-Int. 331. Then it is immaterial, is it not, *how* this deformation or loss occurs, provided it be not too great?

Ans. If I understand the question correctly, you assume the transmission of speech by the production and utilization of electrical undulations similar to the sound waves, and that there is produced

in some way not stated, some deformation or loss which impairs the similarity of form only to so slight an extent as not to seriously interfere with the transmission of speech, and merely inquire whether the mode in which this deformation is produced is material. I do not see that it is.

Cross-Int. 332. In your Ans. to Int. 21 you say, the italics being mine, "Any departure from similarity" [between the form of the electrical undulations and the form of the sound waves] "impairs the character of the speech to the extent to which it occurs, and when that departure or any extraneous disturbance reaches *a certain point* the sounds at the receiver cease to be intelligible as speech."

What is the "certain point" to which you thus refer."

Ans. The expression is not a mathematical one, and cannot be accurately stated. The truth embodied in it, however, I think is clear that when the departure from similarity has reached a certain extent speech becomes unintelligible. Precisely what extent, depends upon various circumstances, and would vary with different persons.

Cross-Int. 333. Would the instrument be operating on Bell's method up to that undefined and apparently undefinable point, and cease to employ Bell's method when that point is reached ?

Ans. So far as it operated I should think Bell's method would be employed, even after the speech became unintelligible ; because vocal sounds would still be transmitted by the electrical undulations. I assume of course that what is heard is heard because of the similarity which remains, rather than because of the dissimilarity which has been introduced.

Cross-Int. 334. Then the incapacity of a telephone to reproduce speech is of itself no evidence that the instrument does not embody Bell's invention?

Ans. It does not seem to me that it is, necessarily.

Cross-Int. 335. This I suppose would be equally true of instruments older than Bell's date, and of those later?

Ans. I do not see that the date of the instrument affects this question.

Cross-Int. 336. In the Dowd case case you testified as follows, italics mine : —

"*Int.* 34. What must a speaking telephone accomplish with reference to the form of vibration in order to transmit articulate speech, or to transmit those peculiar qualities which distinguish one sound from another sound when all are what are called of the same pitch and loudness?

"*Ans.* The transmitter must take up from the air particles, motions which correspond to those of the air particles themselves, and the receiver must reproduce these motions in all their complexity.

"*Int.* 35. What characteristics must an apparatus possess in order to be able to accomplish this?

"*Ans.* In an electrical speaking telephone the connection between the transmitter and receiver must be such that the latter shall not be acted upon merely *at separate intervals*, but the armature or other moving portion of the receiver must be *constantly* under the influence of and guided by the variations in the electrical current caused by the motions of the armature or other vibrating portion of the transmitter; and this vibrating portion of the transmitter itself must be able to substantially take up the complex motions of the air particles which act upon it . . . . *The electrical circuit of the instrument must always present an uninterrupted path, by which the continually varying current may travel from the transmitter to the receiver*, that is, the circuit containing the battery or other source of electrical power, the transmitter, line wire, receiver and earth or return wire, *must always be closed*."

Do you still adhere to the statements contained in this last answer, without qualifications?

Ans. In giving those answers, in June, 1879, I was endeavoring to explain the elementary principles of a new art, and almost a new branch of science, and hence, confined myself to those points which it was essential to have understood; making concise and definite statements, which were, as a whole, absolutely correct of a theoretically perfect instrument; and without attempting to point out the various defects which might be tolerated in practice. I had no reason to consider various minor points with which I was not then unfamiliar, but which I have studied since at great length. In the sense in which I made these statements, I still adhere to them. Of course, if I were considering such points as I have been led to consider in connection with the present deposition, while not departing from the sense of the statements quoted by you, I should naturally be somewhat more prolix in my answers, and call attention to various trifling limitations and exceptions.

(N. J. McDONOUGH)

Cross-Int. 337. If the air waves, generated by the action of a telephonic receiver, be such as to produce sounds recognizably similar to those uttered into the transmitter, but the *electrical current* does not consist of undulations substantially similar in form to that of the original sound waves, but is either intermittent or pulsatory, would Bell's method or Bell's apparatus be employed?

Ans. I should think not.

Cross-Int. 338. Would it make any difference whether the sounds referred to in the last question were those of human speech or any other kind?

Ans. Not so long as the current used does not consist of undulations substantially similar in form to the sound waves.

Cross-Int. 339. If there should be an actual interruption of the telephonic circuit and current as often as once for each fundamental vibration of the transmitting diaphragm, would the electrical undulations of the line cease to be "similar in form" to the sound waves; and would the current become intermittent in character?

Ans. I should not think that it would necessarily. I should wish, however, to study the subject experimentally before giving a final opinion on this point.

Cross-Int. 340. Then, according to your present knowledge, you think it possible, do you not, that the telephonic circuit may be broken at least once for each principal vibration of the transmitting diaphragm without destroying similarity of form between the electrical undulations and the air waves?

Ans. I am not ready to say that it is impossible under all circumstances.

Cross-Int. 341. Then of course with your present knowledge you are not prepared to say that it is impossible to transmit speech with a telephonic apparatus in which the circuit is broken at least once for each principal vibration of the transmitting diaphragm?

Ans. I cannot say that it is impossible under all circumstances. Of course I understand this question, like the preceding, to be a broad one, and not referring to any specific apparatus.

Cross-Int. 342. In the course of your answer to Int. 7 (p. 87) you have said, —

"With any circuit-breaking instrument, the loudness and quality of the sound produced at the receiving station are dependent solely upon the physical construction and action of the receiving instrument itself, and of the battery or other source of electricity by which the transmitter is acted upon.

"The intensity and quality of the sound produced at the receiving station are, therefore, with such an instrument, entirely independent of the intensity and quality of the original sound produced at the transmitting station.

It is for this reason that an instrument of this class, such as, of example, the well-known Reis instrument, operating in the manner described," [by which I understand you to mean the manner described by Reis in his lecture of 1861, and his circular of 1863] "is incapable of transmitting either intensity or quality, and hence is incapable of transmitting articulate speech.

"As will be seen from what I have already said, the Reis transmitter, or any other transmitter which operates by making and breaking the circuit, is capable of transmitting pitch and pitch only."

Does it not follow logically from this, and do you not hold that the transmitter of any telephonic apparatus in which the *intensity* or *loudness* of the reproduced sound is not "entirely independent of the intensity and quality of the original sound produced at the transmitting station," is not a circuit-breaking instrument?

Ans. I do not hold, and I do not think it follows from the statements which you quote, that an instrument ceases to be a circuit-breaking instrument because some variation in the intensity of the sound emitted by the receiver may occur when there is a variation in the vibrations of the transmitter.

Cross-Int. 343. Will it then be true, as stated by you in the passage above quoted, that with a circuit-breaking instrument the "intensity and quality of the sound produced at the receiving station are . . . *entirely independent of* the intensity and quality of the original sound?

Ans. Not in the sense which you attach to the words "entirely independent," but nevertheless true in the sense in which I use those words. I meant to be understood as saying that the intensity and quality of the sound produced by the receiver were not primarily dependent upon and due to, and were not chiefly influenced by, and bore no determinate and definite relation to the intensity and quality of the original sound. I certainly did not mean to state that sounds

of all degrees of loudness would necessarily and in all cases produce precisely the same loudness of sound at the receiver. In other words the largest variations in the intensity and quality of the sound produced at the receiver might take place without the slightest variations in the intensity and quality of the original sound at the transmitter.

Cross-Int. 344. In the Dowd case you testified as follows:—

"*Int.* 20. What is it that distinguishes from each other the various sounds produced by various instruments, such as a violin, cornet or human voice, and which distinguishes these sounds from the simple sound of the tuning-fork, when all are of what we call the same pitch?

"*Ans.* These differences are what are called differences in *timbre* or quality . . .

"*Int.* 23. What is it that distinguishes the sound of one voice from the sound of another voice, when they both utter the same vowel at the same pitch; or which distinguishes one vowel sound from another vowel sound when both are uttered by the same voice at the same pitch?

"*Ans.* These again are differences in quality of the sound in question. As in the preceding cases, variations in the number, pitch, and relative intensity of the overtones present determine the quality.

"*Int.* 24. What is it that distinguishes one syllable from another, in articulate speech, when both are uttered by the same voice and in the same pitch?"

"*Ans.* This same difference in quality, as explained in the preceding cases."

Do you still hold to the views thus and then expressed?

Ans. I have seen no reason for changing them.

Cross-Int. 345. Are you familiar with the teleloge described in the application for a patent made by James W. McDonough, April 10, 1876?

Ans. I believe that I am.

Cross-Int. 346. If that apparatus were so used that the arch piece of the transmitter would not break the circuit, would it employ Bell's method as set forth in the fifth claim of his first patent? I assume the McDonough instrument to be transmitting speech.

Ans. In the case supposed, as I understand it, the transmitter would act as a microphone, and Bell's method would be employed.

Cross-Int. 347. Suppose it to be used in the manner indicated in

the last question, but not in the transmission of speech, would it still employ Bell's method?

Ans. I should think that it would, provided sounds were transmitted by it; assuming that under these circumstances there are produced electrical undulations similar to the air waves.

[*Answer objected to as not responsive.*]

Cross-Int. 348. If McDonough's teleloge were acted upon by sound waves in such a manner as not to cause the electrodes to break contact, would it embody Bell's invention, the fifth claim of his first patent?

Ans. In my opinion it would, since it would then act as a microphone.

Cross-Int. 349. Would it, even if you should find it impossible to transmit speech with it?

Ans. I should think that it would embody the invention, although very imperfectly, since whatever it produced was produced by electrical undulations similar in form to the air waves.

[*Adjourned.*]

DECEMBER 10, 1886. 2.15 P. M.

Cross-Int. 350. As I understand your testimony, the reason why in your opinion a break of contact between the electrodes of a telephone transmitter interferes with the reproduction of speech in the receiver, is that the current is interrupted by the break, and thus, for the time being, the transmitter loses its control over the receiver,—is this correct?

Ans. It is correct as far as it goes, but it is not apparently complete. At the same moment that the control of the current over the receiver ceases, abnormal vibrations are produced which deaden the sensibility of the ear, and prevent it from appreciating sounds that are produced when the current has again assumed control.

Cross-Int. 351. Will the interruption of the current produced by a break of the circuit at any other point interfere with the reproduction of speech, the same as if the break occurred between the electrodes?

Ans. Not necessarily. Thus in the ordinary arrangement, with an induction coil, breaks may occur in the secondary circuit without

such serious effects as if they took place at the electrodes or elsewhere in the primary circuit.

Cross-Int. 352. Looking simply at the *primary* circuit, will it make any difference in the effect produced on the receiver that the break occurs between the electrodes as compared with any other point of the circuit?

Ans. I have never observed any differences. In all cases the most marked disturbances result from breaking the circuit.

Cross-Int. 353. Do you think any difference would be produced by making the break at one point rather than at another?

Ans. I should not expect to find any marked difference.

Cross-Int. 354. The one you think will be equally destructive of speech with the other?

Ans. I should think so. Of course I assume that the manner of breaking, the nature of the electrodes, and other circumstances are the same; and that it is simply the locality of the break that is under consideration.

Cross-Int. 355. In certain places in your direct testimony you have spoken of using a break wheel for interrupting a telephonic circuit. Did you find that such wheel producing actual breaks in the circuit destroys the power of the apparatus to transmit speech?

Ans. That has been the result of my experiments when the break wheel was placed in the battery circuit.

Cross-Int. 356. What telephone was used?

Ans. Among others, the Blake transmitter and the Bell magneto receiver.

Cross-Int. 357. What was the arrangement of the break wheel relatively to the circuit?

Ans. The break wheel, in certain of the experiments, consisted of a brass wheel about a foot in diameter, and into whose circumference were set one or a number of thin strips of ebonite, an insulating material. The wheel was mounted upon a rotating machine so that a rapid revolution could be communicated to it. A somewhat stiff metallic spring pressed against the circumference of the disk. One of the leading wires from the battery was connected with this spring. From the other terminal of the battery a wire ran to the metallic axis on which the brass wheel was mounted. A Blake or other mi-

crophone transmitter and a Bell receiver were interposed in the circuit. On rotating the wheel, the circuit was broken whenever an ebonite strip passed under the spring.

Cross-Int. 358. Did you ever try this break wheel in the secondary circuit of a Blake transmitter?

Ans. I have done so, and have detailed the results in some former depositions.

Cross-Int. 359. Did you find it always impossible to reproduce speech when the wheel was interrupting the secondary circuit?

Ans. I did not. Speech could be transmitted in spite of the interruptions, though these produced very evident disturbances.

Cross-Int. 360. How rapidly could you break the secondary circuit without destroying the capacity of the instrument to transmit speech?

Ans. I cannot state definite figures without reference to my notes, or to statements which I have made with the experiments fresh in mind. My remembrance is that, even when I rotated the wheel very rapidly so that the interruptions in the current (perhaps two or three hundred in a second) produced a musical note, speech could still be transmitted, and from this limit downward it was still possible to transmit speech.

Cross-Int. 361. Do you understand that in a telephone which employs the induction coil, the form of the electrical undulations in the secondary wire is dependent upon, and substantially the same as that of the primary wire?

Ans. I do.

Cross-Int. 362. In the printed record of our deposition in the Long Distance telephone suit, I find the following statement in answer to Cross-Int. 54 :—

"If I heard with a telephonic apparatus a correct reproduction of speech, my own belief would be that this was transmitted by employing electrical undulations similar in form to the air waves. I could not, without examining the apparatus, say that this was certainly the case unless I knew beyond the possibility of a doubt, that by no other method except by employing electrical undulations could speech be transmitted electrically. I know of no other method, and have not been able to conceive of any; but I cannot say that it is absolutely certain that no other method is available."

Did you so testify?

Ans. I did. What you have quoted is a portion of one of my answers in that case.

Cross-Int. 363. Do you to-day know of any reason for retracting or modifying the views thus expressed?

Ans. I do not. I think, however, that the statements there made, as I have said in the first portion of my answer quoted from the Long Distance suit, should be read in the light of my answer to the preceding question in that record in order that they may be clearly understood.

Cross-Int. 364. Int. 51 of the present suit and the answer thereto are as follows:

"*Int.* 51. What do your experiments show as to whether electrical undulations similar in form to the sonorous vibrations due to a spoken word can, in point of fact, be produced by a series of breaks between contact electrodes actuated by a diaphragm acted on by the voice, and as to whether any breaks which such an apparatus can produce are in fact helpful or hurtful in the transmission of speech?

"*Ans.* My experiments have convinced me of the impossibility of producing such electrical undulations by any apparatus which operates simply by producing a series of breaks between contact electrodes arranged and operated as suggested in the question, and also that any breaks produced between such contact electrodes are never helpful and always harmful in the transmission of speech."

What significance did you attach to the word "simply" in making that answer?

Ans. I meant in which the only electrical operation and variation was that produced because of the simple make or break of contact, as distinct from electrical changes produced during the duration of the contact.

Cross-Int. 365. Approximately, how many different forms of speaking telephone transmitters are there?

Ans. I should think there were scores, if not hundreds of them. Many of them, however, present only trifling peculiarities.

Cross-Int. 366. Approximately, how many different forms of speaking telephone receivers are there?

Ans. I should answer in the same words as in my reply to the last question.

Cross-Int. 367. Do you know of or can you conceive of any speaking telephone transmitter which does not produce electrical undulations similar in form to the sound waves, and which, therefore, in your opinion, does not embody the method and apparatus of the fifth claim of Bell's first patent?

Ans. I have never been able to conceive of any.

Cross-Int. 368. Whom do you regard as the inventor of the microphone?

[*Objected to as immaterial and irrelevant to the issues in this cause.*]

Ans. The earliest reference to a microphone that I have seen is in a caveat by E. Berliner in 1877.

Cross-Int. 369. You assume that the microphone was invented later than the date of Bell's first patent, do you not?

Ans. I do, as I have seen no previous reference to it.

Cross-Int. 370. You do not find it described in Bell's patent?

Ans. Not as distinct from other forms of the transmitter which vary the resistance. There is no reference whatever to it specifically in the patent.

Cross-Int. 371. Wherein does the microphone differ from other modes of varying the resistance of the circuit?

Ans. In the microphone there are two electrodes in contact, and the resistance is varied by varying the pressure between them.

Cross-Int. 372. It was well known to electricians, was it not, prior to the Bell patent, that the resistance of a circuit could be varied by varying the pressure between two electrodes in contact?

Ans It was, as I have stated in my answer to Int. 23.

Cross-Int. 373. Are you satisfied with your definition of a microphone, which forms a part of your answer to Int. 25. as follows:

"The microphone consists physically of two electrodes placed normally in contact with a slight pressure, and forming part of a circuit supplied with a current from a battery?"

Ans. I am not satisfied with that statement as a *definition* of a microphone. It is simply a statement regarding the microphone which is given in a very long answer in connection with other state-

ments, the whole of which should be read in order that my meaning may be clear. I think that the statement quoted by you is true.

Cross-Int. 374. Are you then satisfied with this, as a definition of the microphone; I quote from your testimony in the Spencer suit, as follows:

"*Cross-Int.* 36. What do you understand to be the essential features of the microphone?"

"*Ans.* Two conducting surfaces in contact with each other, of such nature that variations in pressure caused by sound shall produce corresponding variations in resistance, and connected in electrical circuit."

[*Adjourned.*]

DECEMBER 11.

Ans. It seems to me that I have correctly stated the essential features of the microphone in the answer quoted.

Cross-Int. 375. Do you regard the use of the microphone as an important improvement in the art of telephony, as compared with anything that is specifically shown and described in Bell's first patent?

Ans. I certainly think that the use of the microphone is a very marked improvement in the art of telephony, as that art existed immediately after the publication of Mr. Bell's patent, No. 174,465.

Cross-Int. 376. Have you ever applied to the apparatus of the defendants in this case, any experimental test for determining whether the apparatus employs the undulatory current, other than the test of listening at the receiver?

Ans. This is the only direct positive experimental test that I have applied. I have tried a good many experiments with microphones like those of the Exhibit Defendants' Transmitter, similar in their character to the experiments which I have tried with other microphones, and already referred to; together with certain additional experiments. The result of these experiments has uniformly been to confirm me in the belief that the instrument referred to in your question is a microphone operating like other instruments of that class, and producing electrical undulations.

Cross-Int. 377. Have you ever in any of those experiments secured a diagram of the current, whereby you were able to prove it to be undulatory?

Ans. I have not.

Cross-Int. 378. Can defendants' apparatus be talked to in such a way that the speech uttered into the transmitter will not be produced at the receiver?

Ans. I do not recollect that distinctly from experiment, but I have a very strong impression that such is the case.

Cross-Int. 379. Would the result, as you understand it, arise from the breaking of contact between the electrodes?

Ans. Either from the absolute breaking of contact, or from abnormal disturbances without actual rupture of contact.

Cross-Int. 380. You can't tell which?

Ans. I could probably tell which if I were experimenting with the instrument. Either of them could produce disturbing effects sufficient to destroy articulation.

Cross-Int. 381. In your opinion, is there any limit to the size of the diaphragm of a telephone, necessary to bring the instrument within the scope of claim five of the Bell patent?

Ans. I understand you to ask me whether there is any limit to the size of diaphragm, which, in connection with suitable apparatus, is capable of producing electrical undulations similar to the sound waves. I do not think that there is. I should suppose that in any case if the operative electrical undulations were similar in form to the air waves, the apparatus would embody the invention set forth in the fifth claim.

Cross-Int. 382. In your opinion, is the constant control of the transmitter over the receiver as necessary in the electrical transmission of any other class of sounds as of those of human speech?

Ans. It is as necessary for their perfect transmission and reproduction.

Cross-Int. 383. Also as necessary for the same degree of imperfect transmission and reproduction?

Ans. I do not know exactly what I am to understand by "the same degree," since I do not know what measure of distortion you have in mind.

[*Defendants' counsel states that he has asked this last question because, as he understands it, such a thing as the* "perfect *trans-*

mission and reproduction" of a sound by an electric telephone is absolutely impossible, whatever the class of sounds may be,]

[*Witness resumes.*] Mathematically it is. But the greater complexity of vocal utterances renders a more perfect control of the transmitter over the receiver necessary, than is required with, for example, ordinary musical instruments. A degree of imperfection which rendered speech unintelligible, though still allowing us to recognize that vocal sounds were transmitted, would not so greatly interfere practically with the transmission of the sound of a trumpet, though it would alter to a greater or less extent the quality of the tone produced by this instrument.

Cross-Int. 384. The fifth claim of Bell's first patent, I think you have testified, is not limited to an apparatus for the transmission of *articulate speech?*

Int. I see no reason why it should be so limited.

Cross-Int. 385. I understand you also to have testified in substance, that if you were to hear speech recognizably reproduced in a telephone, you would regard that fact alone as proof that the apparatus and also its mode of operation were that referred to in the fifth claim of Bell's patent. If now you were experimenting with a telephone lacking in the sensitiveness and perfection necessary for the transmission and reproduction of *speech*, but were to find it capable of recognizably reproducing other kinds of sounds, such recognition being effected by the reproduced quality of such sound, would you deem that fact proof that the apparatus and its mode of operation were that referred in the fifth claim of Bell's first patent?

Ans. I cannot answer this question absolutely and broadly without carrying on quite a series of acoustic investigations. In making this answer I assume that by recognizable reproduction of quality you mean such a reproduction of quality as shall enable one to know the general character of the sound transmitted. If, however, I found an instrument capable of recognizably reproducing the quality of all other kinds of sounds, unless I should have very strong evidence to the contrary, I should believe that the apparatus operated according to the method described in the fifth claim,

Cross-Int. 386. Do you then assume that there may be a telephone by means of which you can recognizably reproduce the

quality of some classes of sounds, which would not be within Bell's fifth claim?

Ans. I do not wish to make any assumption regarding an apparatus which is purely hypothetical. I know of no such apparatus, but I am not ready to say that an instrument could not be devised, by means of which, at the receiver, I should know, for example, that it was a trumpet and not a drum or fife that was sounded at the transmitter, even though what would unquestionably be called electrical undulations are not produced.

Cross-Int. 387. Do you not hold that it is the capacity of reproducing the *quality* of sounds that distinguishes Bell's apparatus and method from those that had preceded him?

Ans. The essential peculiarity of Mr. Bell's apparatus and method is that they employ electrical undulations similar to the air waves. The reproduction of quality is a consequence of this.

Cross-Int. 388. And you know of no method, if I have understood your testimony aright, whereby quality can be reproduced except by employing electrical undulations similar in form to the air waves?

Ans. I do not.

Cross-Int. 389. Then is it not fair to say that, *practically*, the substantial difference between Bell's method and apparatus and those which had preceded, is that Bell reproduces quality?

Ans. There is undoubtedly that practical difference between them.

Cross-Int. 390. And yet do you hold that you may have a telephone in which transmitted sounds are recognized by their quality, but which would not be within the scope of the fifth claim of Bell's first patent, even though the apparatus were not sufficiently sensitive to thus reproduce *all* sounds?

Ans. I know of no such instrument, and hold no such opinion. It is a purely hypothetical matter.

Cross-Int. 391. Do you then hold that an apparatus with which you can recognize sounds by their reproduced quality, embodies the invention of Bell's fifth claim, even though the apparatus be not sufficently sensitive to reproduce the more complex sounds of speech?

Ans. I do not see that the fact that the apparatus fails to trans-

mit speech prevents it from employing the method of the fifth claim so far as it is capable of transmitting quality, though it is not sensitive enough to do this with sufficient perfection.

Cross-Int. 392. Do you then answer the question in the affirmative?

Ans. I do, understanding you to assume that the apparatus fails to reproduce speech because of insensitiveness.

Cross-Int. 393. Do you suppose that any plate of iron or steel, or other inductive material which is capable of being put into vibration by an ordinary telephonic current acting upon an electro-magnet, would also be capable of being put into vibration by air waves such as would be produced by one speaking to a telephone?

Ans. I do.

[*Recess.*]

Cross-Int. 394. The following has been furnished by the counsel of the Bell company as a copy of a deposition given by you in the suit of the Harmonic Telegraph Co. *v.* The New England Telephone Company. Please state whether said paper contains a correct statement of the facts to which it purports to relate, so far as the same are within your personal knowledge? The said paper reads as follows:

[COPY.]

HARMONIC TELEGRAPH CO. ET AL. *v.* THE NEW ENGLAND TELEPHONE CO.

HARMONIC TELEGRAPH COMPANY ET AL. *v.* CHARLES WILLIAMS, JR..

EVIDENCE FOR DEFENDANTS.

TAKEN PURSUANT TO THE SIXTY-SEVENTH RULE OF THE SUPREME COURT OF THE UNITED STATES, IN EQUITY, AS AMENDED, BEFORE ME,

W. P. PREBLE, JR., *Examiner.*

Present: CAUSTEN BROWNE, Esq., *of Counsel for Complainants,*
CHAUNCEY SMITH, Esq., *and* J. J. STORROW, Esq., *of Counsel for Defendants.*

[It is agreed that the same deposition shall be considered as taken in both the above-named cases.
Attest: W. P. PREBLE, *Examiner.*]

DEPOSITION OF CHARLES R. CROSS.

BOSTON, June 18, 1879.

Direct Examination by J. J. STORROW, Esq., *of Counsel for Defendants.*

Int. 1. Please state your name, age, residence and occupation.

Ans. Charles Robert Cross; thirty-one years; Boston, Mass.; Thayer Professor of Physics in the Massachusetts Institute of Technology.

Int. 2. Have you, before 1874, ever used any apparatus for sending audible melodies or musical tones produced by currents of electricity sent from the transmitting station? If so, describe such apparatus as you have used, and what use you or others have made of it, within your knowledge, before 1874, and when and where such use took place.

Ans. Previous to 1874, I occasionally used the receiver of the Reiss telephone, with a tuning-fork as a transmitter, arranging the apparatus in the ordinary manner. In February, 1872, I exhibited another form of apparatus, designed to accomplish the same end, at a lecture given before the pupils of the New England Conservatory of Music. The apparatus made use of the principle previously employed by Prof. E. C. Pickering, then of the Institute of Technology, in an experiment privately performed. In the apparatus exhibited by me, a horseshoe electro-magnet was placed upon a wooden box so that its poles were close to the exterior of a large tin box, which is here present, but not quite touching it. The magnet was placed in an electric circuit with a battery of six small Grove cells, a tuning-fork being also placed in the circuit, so arranged that, on vibrating the fork, the current was made and broken a great number of times a second. The sound of the tuning-fork was reproduced by this receiver, and the sound from the receiver was perfectly audible throughout my lecture room. In the last part of December, 1873, and the first week in January, 1874, a number of other experiments were tried, and a second exhibition of the instrument was made on Jan. 7, 1874, at a lecture in one of the Lowell free courses, at the Institute of Technology. In the latter experiments, several forks were tried separately, and the receiver reproduced the characteristic pitch of each. But one fork was, however, used publicly in the lecture. At certain times during the experiments, the magnet touched the box, in which case the sound persisted, but was less loud.

Int. 3. Does that apparatus exist now in the same condition as when you used it, and if so, where does it belong, and is it here present?

Ans. The separate portions of the apparatus still exist, belonging to the Institute of Technology. The different portions of the receiving instrument are these which are here at present. Two binding screws have been added to the magnet since the date when the experiment was performed.

Int. 4. Was this magnet and the wooden box on which it rested and the large tin box made for the purpose of this exhibition, or where did you get them?

Ans. None of the portions of the apparatus in question were made for the exhibition. The electro-magnet was one which had been for some years in the possession of the Institute. The large tin box was one in which some apparatus had been imported a year

or more previous to the date of the experiments. The wooden box which was used, was one which was convenient for use as a stand upon which to place the electro-magnet. I cannot say that the wooden box present to-day is the identical one then used.

Int. 5. What led to the preparation of this apparatus, and for what purpose was it prepared?

Ans. I took up the subject chiefly to be able to show in my lectures an instrument which would give louder sounds than the Reiss receiver would produce with the transmitter which I used.

Int. 6. You say that this apparatus was suggested by a previous experiment of Professor Pickering; state what you knew of that experiment before you made this apparatus.

Ans. The experiment was performed as early as 1870. I was not present at the time, but the experiment was described to me on the following day. The receiver was a tin plate or box, which I saw afterwards myself. I cannot say positively whether it was a plate or a box which I saw, or whether there was or was not an armature attached. The transmitter, as I was informed at that time, was a sonometer to the wire of which a small wire acting as a circuit-breaker was attached, and the whole so connected with the battery that on causing the wire of the sonometer to vibrate, the circuit was made and broken with great frequency. The effect of this was to produce a loud noise at the instrument used as a receiver, while the sonometer wire was vibrating. The description was given to me by Mr. Waldo Ross of this city, who was present at the experiment, and I think also by Professor Pickering. The box used in my later experiments was not the one made use of in the earlier experiments of Professor Pickering.

Int. 7. When this experiment of Professor Pickering was described to you at the time you have stated, were you informed in what position the tin box or plate was placed with reference to the poles of the magnet, and if so, what were you informed on the subject?

Ans. All that I distinctly recollect is that the magnet was so placed that its poles were very near to the metal of the plate or box.

Int. 8. Have you recently, with the receiving apparatus which you constructed in 1872, and which is here present, tried to transmit and reproduce audibly articulate speech or the sound of musical instruments transmitted by means of electricity from a distant station? And if so, describe what you have done in that respect, and with what results?

Ans. On the tenth of June, 1879, I tried a number of experiments with this receiver, which was set up in a manner similar to its arrangement in the exhibition already mentioned, it being in the office of Mr. J. J. Storrow, Union Building, State Street, Boston. It, together with a Blake transmitter, was connected in the primary circuit of a battery, the transmitter being placed in room 42 in Union

Building, and connected with the receiver by wires stretching across the open court separating these two rooms, and about one hundred feet in length. A second circuit containing two ordinary hand telephones was stretched between the two rooms, so that any messages sent by the apparatus which I am describing could easily be verified.

The magnet in these experiments was placed near to the outside of one end of the tin box, which rested upon its side, and when faint sounds were transmitted, the head was placed inside the box, with the ear opposite the poles of the magnet, in order to detect these sounds. I first asked Mr. Watson, who was assisting me, to play a small mouth harmonica before the mouthpiece of the Blake transmitter. I was expecting to hear the sound given by that instrument, and so was somewhat surprised to hear loud and clear notes resembling those of a music box. On inquiring of Mr. Watson what instrument he had been using, I was informed that he had been transmitting the sound produced by a child's music box, which he happened to have there. Afterwards the mouth harmonica was substituted, and its characteristic notes clearly perceived. In both of these cases, the characteristic pitch and quality of the tones in the musical instruments used could be heard at the distance of eighteen inches or more from the receiver. Mr. Watson was then asked to speak into the transmitter, and while the ear was still at a distance of about fifteen inches from the receiver, a sound was heard, which was recognized as articulation, although the words could not be distinguished at that distance. I then placed my ear close to that portion of the box which was opposite the poles of the magnet, and asked Mr. Watson to speak into the transmitter. I then without difficulty was able to hear a number of sentences, which were entirely unexpected to me.

Int. 9. Please state whether on this occasion you also tried to transmit articulate speech, using as a receiver a common hand Bell telephone connected upon the circuit with the mouthpiece and ordinary diaphragm removed, and the instrument held against one end of the tin box, so that the box should take the place of the diaphragm; and if so, with what result.

Ans. I did. With it we succeeded in transmitting articulate speech from one station to the other with very great ease.

Int. 10. Will the Institute of Technology give or sell the defendants the receiving apparatus you constructed, to be filed as an exhibit in this case; and if not, will you please produce duplicates of said tin box and horseshoe electro-magnet, and a wooden box like the one used in your experiment?

Ans. These early experiments have so much interest attached to them that it seems desirable to retain the original apparatus in the possession of the Department of Physics. I will produce duplicates.

(N. J. McDONOUGH)

[*Defendants offer in evidence duplicates of the tin box, horseshoe electro-magnet and wooden box, marked "Defendant's Exhibits* 1, 2 *and* 3 *Cross Metallic Diaphragm Magnet Receiver, W. P. Preble, Jr., Examiner.*"]

Int. 11. Do you expect immediately to go away; if so, how soon, and for how long?

Ans I expect to leave for Europe on Saturday next, to be gone until the latter part of September.

[*Adjourned to June* 19.]

BOSTON, June 19, 1879.

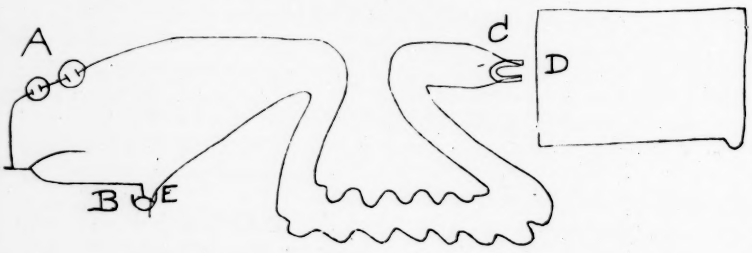
Int. 12. Have you any way of fixing the dates given in your second answer other than by memory; if so, state what it is.

Ans. The date of the earliest exhibition, February, 1872, is indicated upon my notes used at the lecture given at that time. That the second public exhibition was given at the date assigned, I know from the fact that it was given in the first of a course of lectures on sound; a reference to the advertisements of that course gave me the date which I assigned, Jan. 7, 1874.

Int. 13. Please to produce, as part of your answer, a diagram illustrating the mode in which you connected up the tuning-fork and the Cross Metallic Diaphragm Magnet Receiver in the exhibitions of the Institute of Technology, referred to in your deposition.

Ans. I produce it.

EXHIBIT 4.



A, Battery.
B, Tuning-fork circuit-breaker.
C, Electro magnet.
D, Tin box.
E, Mercury cup.

Int. 14. Please also produce, as a part of your answer, a diagram of the manner in which you connected up the said receiver with the Blake transmitter, in the experiments in which you transmitted

articulate speech and musical tones on June 10, 1879, to which you have testified in this deposition.

Ans. I produce it.

A, Battery.
B, Blake transmitter in main circuit.
C, Magnet.
D, Tin box.

(Signed) CHAS. R. CROSS.

(Signed)

Attest: W. P. PREBLE, Jr., *Examiner*,

Ans. It does.

Cross-Int. 395. What was the size, as near as you recall, of the tin box used in the experiments described above in your deposition in the Harmonic telegraph case?

Ans. Somewhere about three feet long, twenty inches broad, and twenty inches deep, as nearly as I can estimate its size.

Cross-Int. 396. Regarded simply as an electrical apparatus for reproducing sound, wherein did the receiver used by you in those experiments differ in principle of operation from the receiver shown and described in Bell's first patent?

Ans. The apparatus in question did not, properly speaking, reproduce sound. It simply gave forth a sound corresponding to a determinate number of breaks of a tuning-fork, the receiver giving forth a sound, even though the sound of the tuning-fork was not audible. The receiver differed in its principle of operation from the receiver in the first Bell patent in that the metal plate simply moved toward the electro-magnet when the circuit was made, and away from it when the circuit was broken, in the latter circumstance moving with a velocity dependent only upon its physical structure.

Cross-Int. 397. My question was not intended to be limited to your experiments of 1872 and 1874; but to include also, those of 1879.

Ans. In the experiments of 1879, the principle according to which the receiver operated was the same as that according to which the receiver of the first Bell patent operates.

Cross-Int. 398. In your public lectures in which you described this apparatus in 1872, or thereabouts, did you make any suggestion, and if so what, in regard to the possibility of utilizing it, or any portion of it, for the electrical transmission of speech?

Ans. In my lecture of 1872, I suggested that with some modification of the transmitter, it might be possible to transmit the songs and the music of the forthcoming Peace Jubilee over the whole country.

Cross-Int. 399. Did you make any suggestion about transmitting speech?

Ans. If I recollect rightly, I did; but in the reference which I have just made I referred to the transmission of the words of vocal music.

Cross-Int. 400. Did you at that time know of the Reis telephone?

Ans. I did.

Cross-Int. 401. Which form?

Ans. The cubical box transmitter, and the knitting-needle receiver as made by Koenig.

Cross-Int. 402. When first did you see a Reis telephone?

Ans. I do not recollect; but it was not until after 1876. We had in our cabinet of apparatus an instrument for producing the Page music, which was similar in its construction to the Reis receiver, though much larger.

Cross-Int. 403. I have understood that early in 1874 you described to Mr. Bell the apparatus with which you experimented in '72, as described in your Harmonic Telegraph deposition, did you?

Ans. I did; sometime in the spring of 1874, if I recollect rightly.

Cross-Int. 404. Did the sounds which you got from the receiving apparatus in those experiments of 1872 and 1874 resemble at all the sounds given off by a tuning-fork?

Ans. They had the same pitch.

Cross-Int. 406. What were they like, otherwise?

Ans. They were generally much louder than the fork, and their quality was entirely different, being fuller and musically more like the note of a deep organ pipe.

Cross-Int. 407. Did it seem to you to be in any respect the note of a tuning-fork?

Ans. It did not; except, of course, as all grave notes present less dissimilarity than notes of moderate height.

Cross-Int. 408. In some of the points alleged to represent Reis's bored block transmitter, I have seen an adjusting screw, apparently for the purpose of regulating the relation of the electrodes. Do you know of the presence of any such device in any representations or descriptions of the Reis instrument prior to 1876?

Ans. I do not.

Cross-Int. 409. Would such a device constitute a material modification of the Reis apparatus?

Ans. That would depend very much upon how it was to be used.

Cross-Int. 410. Why?

Ans. If it were to be put in, as I have known it to be put in in some instruments that I have seen, in order to use it not as a circuit-breaker, but as a microphone, I should consider it a material modification. If it were put in with the express object of securing more certainly, the desired breaking of the current, I should not think it a very material modification.

Cross-Int. 411. Have you any doubt that Reis devised his telephone with the hope that he would be able thereby to transmit speech electrically? I call your attention particularly to the following language in his lecture of 1861: —

"How, indeed, could a single instrument reproduce the combined effect of all the organs employed in human speech? This was always the cardinal question."

Ans. I have not.

Cross-Int. 412. If you were to have put before you one of Reis's bored block instruments provided with an adjusting screw by means of which the relation of the electrodes could be regulated, and were to experiment with the same for the purpose of accomplishing what

you say Reis hoped to accomplish, to wit: — the transmission of speech, and were not instructed as to any particular adjustment of the screw, what adjustment would you give it?

[*Objected to as immaterial and irrelevant in view of the knowledge of any one skilled in the art created by Bell's invention; and as inadmissible and incompetent, if it were possible to exclude the influence of that invention from the mind of an expert interrogated at this date.*]

I will modify the question so that it shall relate to the period prior to your knowledge of Bell's invention. If prior to that time such an apparatus had been laid before you under the conditions named, what adjustment do you think that you, as an experienced experimenter in physics, would have given to the screw?

[*Objected to as inadmissible and incompetent.*]

Ans. So far as I can judge, I should have adjusted the electrodes so as to make and break contract when spoken to.

Cross-Int. 413. If under such adjustment you found that the instrument would not accomplish the purpose which it is assumed Reis had in view in creating it, to wit, the transmission of speech, do you think that you would then have changed the adjustment?

[*Same objection*].

Ans. I cannot say. My inventiveness might have led me to change the adjustment, and perhaps to change the materials of the electrodes, and perhaps further to increase the mass of the anvil electrode, and so to make a new and important invention; or much more likely on the other hand, judging from what I now know of the instrument, I should have given the matter up as a bad job.

Cross-Int. 414. Do you really think if you had been making a serious test of such an instrument, you would have tried but a single adjustment of the electrodes?

[*Same objection.*]

Ans. Doubtless not. I imagine that I should have tried to vary the distance of the electrodes so as to give greater or less length of break. I see no reason to suppose, however, that I should have attempted any other adjustment than such as would give these breaks. Certainly I should not have done so unless I had conceived of some different mode of operation of the instrument from any that I knew prior to the date of Mr. Bell's invention.

Cross-Int. 415. If you had found that, with various adjustments of the electrodes, all, however, permitting a break of contact, you still failed to accomplish the object in mind, the transmission of speech, do you think that you would still persistently have avoided an adjustment that would have allowed the electrodes to remain in contact?

This question proceeds upon the hypothesis embodied in Cross-Int. 412, that you had received no instructions as to the adjustment to be made.

[*Same objection.*]

Ans. If I had the idea, which I did have, that the only way in which the knitting needle could be made to give forth a sound was by making and breaking the circuit; and unless I had learned otherwise from observation and experiment, I see no reason to suppose that I should have chosen an adjustment which would allow the electrodes to remain permanently in contact. What I might have discovered or invented by persistently working in this field, of course I cannot say.

Cross-Int. 416. Have you ever used a Bell receiver with a tuning-fork as a circuit-breaker, for producing sounds in such receiver?

Ans. I have.

Cross-Int. 417. Did you find that there were a great many high and strong overtones given forth by the vibrating plate of the receiver, and which were not present in the sound produced by the tuning-fork?

Ans. That has been my experience.

Cross-Int. 418. What is the explanation?

Ans. The way in which I explain it to myself is as follows: Under the action of the circuit-breaker the diaphragm is violently and suddenly pulled towards the electro-magnet, and then suddenly released. The periodic making and breaking of the circuit by the tuning-fork imposes a corresponding periodicity upon the motions of the diaphragm. This vibration would be graphically represented by a periodic curve of great mathematical irregularity, though its appearance to the eye would not necessarily be very irregular.

This complex curve according to a well-known mathemetical prin-

ciple can be resolved into a series of component sinusoidal curves. These component curves will represent the partial tones due to the motion of the diaphragm. The upper partials will be very prominent, as they always are when a sudden violent impulse is given to a body capable of vibration; as is observed, for example, in the case of a piano string struck by a metallic hammer, or plucked suddenly with the finger nail.

Cross-Int. 419. I understand, on reading one of your affidavits in the Ghegan case, that you have tried the following experiment; taking a break wheel, placing the same in a magneto telephone circuit, and running the same at a speed to produce nine hundred makes and breaks per second, with the result that such breaks did not prevent speech, although they produced a characteristic sound noticeable by the ear as an annoying and disagreeable disturbance. Have you, in fact, performed such experiment with such result?

Ans. I have.

Cross-Int. 420. In that experiment the breaks occupied one half of the entire time, did they not?

Ans. They did.

Cross-Int. 421. What was the magneto telephone used?

Ans. A Bell magneto was used. I do not recollect, without reference to my notes, whether I used any other form or not.

[*Adjourned to Dec.* 16, *at* 11 A. M.]

DECEMBER 16, 1886.

Cross-Int. 422. Have you ever tried the experiment of putting a break wheel or other rheotome into a battery circuit, joining a telephonic transmitter and a telephonic receiver?

Ans. I have done so; using a microphone as a transmitter and a magneto as a receiver, putting the battery and break wheel in direct circuit with these.

Cross-Int. 423. Did you find the break wheel to prevent the transmission of speech in the special experiments that you made?

Ans. I did, if the breaks were at all frequent.

Cross-Int. 424. Please be more specific?

Ans. As nearly as I recollect, the effect was as follows: — when the wheel was revolved slowly, so that the breaks were infrequent, speech could be understood in spite of them. On rotating the wheel faster, it became more and more difficult to understand, so that I should say that when only four or five a second were produced, understanding ceased; though this, of course, depends to some extent on the loudness of the clicks caused by the breaks. The loud noise produced by the clicks deafens the ear, so that it loses the perception of everything else.

Cross-Int. 425. Would the effect of the break, by way of impairing the reproduction of speed, be greater under the circumstances supposed in Cross-Int. 422 than would be the case if the break wheel were placed in the primary battery circuit and the receiver in a secondary circuit?

Ans. I do not think that there would be any material difference, provided, of course, that the resistance of the receiver was suitably proportioned in each case for the reproduction of sound.

Cross-Int. 426. Did you not testify in the Ghegan case that when you put a break wheel in the primary circuit of a microphone telephone, the receiver being in the secondary circuit, you could cause "the makes and breaks to recur with a frequency of between nine and ten times a second," and that notwithstanding the recurrence of such breaks with this frequency, "speech could be transmitted clearly"?

Ans. I did, as I see by reference to the record. From this I

should judge that in my answer to Cross-int. 424 I considerably under-estimated the number of breaks at which speech was obliterated. As I have already said, that statement was made entirely from memory, and without reference to notes; the experiments having been made about four years ago.

Cross-Int. 427. Your said testimony in the Ghegan case was true?

Ans. It was.

Re-direct examination by GEORGE L. ROBERTS, *Esq., of Counsel for Complainants.*

Int. 428. In the particular experiment to which you have just made reference, as described in your testimony in the Ghegan case what was the ratio of the duration of the breaks to the duration of continuity in the circuit between breaks, and what the rate of their recurrence?

Ans. The ratio of the break to the make was about one to nine hundred and twenty-four. The breaks recurred nine or ten times a second, so that a break occupying about $\frac{1}{8600}$ of a second was followed by a make of about $\frac{924}{8600}$ of a second.

Int. 429. What was the practical effect of these breaks, and to what was the speech heard at the receiver due?

Ans. Their effect was, when recurring at the rate mentioned, to produce a harsh sound superposed upon and interfering with the articulation. The speech which was heard at the receiver was caused by the action of the carbon microphone.

Int. 430. Did you, in the course of your experiments referred to in the Ghegan case, ascertain the amount of disturbing effect produced by more frequent recurrence of the breaks made in like manner in the same circuit as that referred to in your answer to Cross-Int. 426; and if so, what did you find to be the result?

Ans. I can best answer this by quoting a statement which I made in my deposition in the Ghegan case, when the experiments were fresh in my mind.

26. "I then changed the break wheel, by inserting twenty-four radial strips of vulcanite, of the same thickness as the first, in place of the one. The results of this were that the breaks now occupied about $\frac{1}{40}$ of the time; that is, a break was followed by a make thirty-nine

times as long; and with the same number of revolutions of the wheel, the breaks would recur twenty-four times as often as before. With the same speeds of the wheel which I had tried before the alteration, the disturbances in the receiving telephone became much more noticeable. As the breaks occupied a larger portion of the time (now $\frac{1}{40}$), more of the true articulating current was lost; but the most noticeable effect was to introduce an abnormal noise, caused by the vibrations due to thus throwing off and on the whole strength of the battery during the brief period of the break. When they occurred more than from about thirty-five to forty times a second, they grew, not into a continuous musical sound, but into a sort of a roar, the effect of which on the ear was such as to prevent it from understanding the words spoken into the transmitter. This experiment was repeated a great many times, and by other persons, with substantially the same results. Among those who took part in them with me were Prof. Wright and Prof. Trowbridge. In these experiments, I used at different times a Blake transmitter and the complainants' Exhibit Hopkins transmitter with substantially the same results.

"27. In some other experiments I used a break wheel with a single strip of vulcanite only $\frac{1}{50}$ of an inch thick, and with which, as the wheel was thirty-seven inches in circumference, the breaks occupied only $\frac{1}{1850}$ of the whole time. The results obtained were substantially the same as with the former disk."

Int. 431. In Cross-Ints. 78, 79, 80 and 81, and in your answers thereto, reference was made to the evidence to be derived from what may be heard through telephonic apparatus, the precise construction of which was not described; and in Cross-Int. 112 the inquiry was concerning "a telephonic apparatus, the transmitter and receiver of which were unknown to you." Similar absence of description of the telephonic apparatus inquired about, exists in Cross-Int. 385, and perhaps elsewhere in your cross-examination. As there are acoustic telephones as well as electric telephones, will you state, to prevent possible misapprehension, whether you made any assumption as to the agency by which the telephonic apparatus so referred to operated?

Ans. I assumed that the telephonic apparatus referred to operated by electricity.

Int. 432. In the course of your cross-examination you have referred to the fact that every variety of form in the curve which graphically represents the vibrations of the air accompanying sounds is resolvable by mathematical analysis into abscissas and ordinates

which represent only pitch and loudness; and you have stated, in substance, that the transmission of pitch due to periodic recurrence of the vibrations, and the transmission of loudness due to the maximum amplitude of those vibrations, will not result in the transmission of quality. Will you please explain this matter somewhat more at length?

[*Question objected to as not accurately representing the testimony of the witness, as defendants' counsel has understood the same.*]

Ans. The quality of a sound depends upon the number, loudness, and relative pitch of the different partial tones. If the pitch and loudness of *each partial tone* can be accurately reproduced, the quality of the original sound can be reproduced. But the reproduction of the rate of vibration of a single partial tone—as, for example, the fundamental; and of the total loudness of the sound, or the loudness of any one partial — as, for example, of the fundamental, without reference to the loudness of each separate partial, cannot reproduce quality.

Int. 433. In your answer to Cross-int. 237 you have expressed your inclination to the opinion that, in the operation of the Reis apparatus there may be variations in the loudness of the sound produced by the receiver, due to variations in the velocity with which the electrodes part contact, and, consequently, as I understand you, to the relative degrees of abruptness with which the breaks in the electric current take place; and in your answers to Cross-int. 238 and Cross-int. 239 you have referred to a certain dependence of the loudness of the sound produced by the receiver of the Reis apparatus upon the pitch, loudness, and quality of the sound which actuates the transmitter. Will you explain more fully this relationship of dependence, and state whether it involves or implies any transmission of quality?

Ans. The abruptness with which contact is broken in the Reis transmitter evidently depends upon the velocity with which the anvil and hammer electrodes separate. Other things remaining the same, this velocity would be greater at a higher pitch, since the rate of motion under these circumstances would be greater. Also, other things remaining the same, the velocity of separation would be greater as the amplitude of vibration and loudness of the sound increased;

but the increase in loudness of the sound at the receiver would not be proportional to the increased amplitude of vibration of the transmitter. Again, differences in quality, other things remaining the same, will produce differences in the rapidity with which one electrode parts contact with the other, and hence in the loudness of the sound in the receiver. These variations in the abruptness of the break, which I have explained, do not imply any transmission or reproduction of quality, or indeed any reproduction of loudness, since the intensity of the sound at the receiver is not proportional to the energy of vibration at the transmitter. It is also evident that variations in the velocity of break due to quality differences depend only upon the absolute rate at which the electrodes separate; and, provided this is the same, the loudness of the sound produced will be the same, whatever may be the peculiar combination of partial tones co-existing in the sound actuating the transmitter.

[*Recess.*]

[*Counsel for the complainants puts in evidence the following publications relating to Charles Bourseul and Philipp Reis — namely:*

BOURSEUL PUBLICATIONS.

No. 1. *L'Illustration, Journal Universel*, August 26, 1854, a newspaper published in Paris, France. A communication from Charles Bourseul,

No. 2. *Didaskalia, Blätter für Geist, Gemüth und Publicität* (Magazine for Intelligence, Humor and News), No. 232, September 28, 1854, a periodical published at Frankfort-on-the-Main, Germany. Apparently an abstract of the foregoing Bourseul article . . . . . .

No. 3. *Exposé des Applications de l'Electricité*., by Du Moncel, Paris, vol. 2, p. 225, ed. 1854; vol. 3, p. 110, ed. 1856. Reprint of the body of Bourseul's communication to *L'Illustration* . . . . . .

No. 4. *Comptes Rendus des Séances de l'Académie des Sciences*, for November 26, 1877, Paris. Extract from paper about Bourseul and Bell, read before the Academy by Du Moncel . . . . . .

No. 5. *The Telephone, the Microphone and the Phonograph*, by Du Moncel, published in French at Paris, in 1878, and in English by Harper Bros., New York, 1879, pp. 12–15 . . . . . .

REIS PUBLICATIONS.

No. 6. *Frankfurter Conversationsblatt*, November 29, 1861. "Reproduction des Schalles durch den galvanischen Strom" (Frankfurt). [It purports to be a report of Reis's Lectures of October and November, 1861] . . . . . .

No. 7. *Jahresbericht des Physikalischen Vereins zu Frankfurt am Main: für des Rechnungs Jahr* 1860–1861 (Yearly Report of the Physical Society at Frankfort-a-M., 1860–61), pp. 57–64 [published in 1862]. "On Telephony by Means of the Galvanic Current, by Philipp Reis." [Reis's lectures revised by himself] . . . . . .

No 8. *Jahresbericht des Physikalischen Vereins zu Frankfurt am Main für das Rechnungs Jahr* 1861–1862. Extract from the "Proceedings"; being the notice of the two lectures by Reis, October 26 and November 16, 1861 . . . . . .

No. 9 *Die Fortschritte der Physik*, XVII., for 1861. pp. 171–3. Article entitled "Ph. Reis, Telephony by means of the Electric Current (Annual Report of the Physical Society of Frankfort-on-the-Main, 1860–1, pp. 57–64)" . . . . . .

No. 10. *Aus der Natur*, vol 21, pp. 470–4, Leipzig, 1862. [Abstract of Reis's Lecture of 1861, with quotations from it] . . . . . .

No. 11. *Didaskalia*, May 8 and May 12, 1862 Extract copied from book of Sylvanus P. Thompson. [Reis exhibitions of May, 1862, before the *Frei Deutsches Hochstift* (Free German Institute)] . . . . .

No. 12. *Zeitschrift des Deutsch-Oesterreichischen Telegraphen Vereins*, Berlin (Journal of the German-Austrian Telegraph Association), vol. 9, p. 125, 1862. Legat Article . . . . . .

Nos. 13, 14, 15. *Deutsche Industrie Zeitung* (Industrial Gazette), 1863, *Chemnitz*. Three articles from different numbers: No. 16. p. 184, April 17, 1863; No. 18. p. 208, May 1, 1863; No. 22, p. 249; May 29, 1863 .

No. 16. Böttger's *Polytechnisches Notizblatt*, 1863, No. 61, p. 81. "On the Transmission of Tones to any desired distance by means of Electricity (Telephony)." [Apparently an abstract of the Reis Lecture],

No. 17. *Frankfurter Conversationsblatt*, June 30, 1863. [Reprint of the Böttger Article] . . . . . .

No. 18. Dingler's *Polytechnisches Journal*, vol. 168, p. 185. [Reprint of the Böttger Article] . . . . . .

No. 19. *Polytechnisches Centralblatt*, 1863, pp. 857–9. [Reprint of the Böttger Article] . . . . . .

No. 20. *Jahresbericht des Physikalischen Vereins zu Frankfurt-am-Main; für das Rechnungs Jahr* 1862–1863, p. 35 (Report of the Physical Society of Frankfort-on-the-Main). Memorandum of Lecture by Reis, July 4, 1863 . . . . . .
1869–1870, p. 26. [Mention of the Reis Lecture of 1861.]

No. 21. Reis's letter to Ladd July 13, 1863. Original in the library of the society; printed in the *Journal of the Society of Telegraph Engineers and of Electricians*, for March, 1883, No. 46 . . . . . .

No. 22. Report of British Association Meeting, from *The Newcastle Daily Chronicle and Northern Counties Advertiser*, Saturday, August 29, 1863 . . . . . .

No. 23. *The Civil Engineer and Architect's Journal*, vol. 26, pp. 307–8, 1863. "Acoustic Telegraph," by W. Ladd. A paper read to the British Association, 1863 . . . . . .

No. 24. Report of the Thirty-Third Meeting of the British Association for the Advancement of Science, in August and September, 1863; published in 1864 . . . . . .

No. 25. Prospectus of J. Wilh. Albert. Frankfort-on-the-Main, August, 1863,

No. 26. Reis's Circular of August, 1863 . . . . . .

No. 27. Reis's Descriptive Circular. 9 August, 1863 . . . . . .

No. 28. Dingler's *Polytechnisches Journal*, vol. 169, p. 23. Reprint of Legat Article . . . . . .

No. 29. Böttger's *Polytechniches Notizblatt*, 1863, No. 15, p. 225. Böttger's Account of Reis's Improved Apparatus, copied in . . . . .

No. 30. Dingler's *Polytechnisches Journal*, vol, 169, p. 399 . . . . .

No. 31. *Die Fortschritte der Physik*. 1863, p. 96 . . . . . .

No. 32. *Dublin Medical Press*, October 14, 1863 . . . . . .

No. 33. *Cosmos*. Weekly Encyclopedic Review of the Progress of the Sciences, Paris, Dec. 25, 1863, vol. 23, p. 705. "Note by M. Koenig."

No. 34. *Zeitschrift des Architectur und Ingenieur Vereins* (Journal of the Society of Architects and Engineers for the Kingdom of Hanover), vol. 12, p. 147. *Dublin Medical Press* Article, condensed . . . . .

No. 35. *Die Gartenlaube* (An illustrated weekly paper of Leipsic), No. 51, December, 1863, "Der Musiktelegraph." Apparently an Abstract of previous articles, with cuts . . . . . .

No. 36. *Cosmos*, vol. 24, pp. 349, 352. Published at Paris, March 22, 1864. Long article, purporting to be written from Koenig's establishment .

No. 37. *Portefeuille Economique des Machines*, Paris, 1864, vol. 9, p 101. Second Saint-Edmé article . . . . . .

No. 38. *Tagesblatt der 39 Versammlung Deutscher Naturforscher*, Giessen, September, 1864. From Sylvanus P. Thompson's book, and there entitled "Extract from the Report of the German Naturalists' Society, held at Giessen (1864)" . . . . . .

No. 39. *Proceedings of the Literary and Philosophical Society of Manchester.* Published at Manchester, 1865. Notice of Reis's telephone, by Prof. Clifton . . . . . .

No. 40. *Annalen du Chemie und Pharmacie*, 1864-65. Foot-note of Buff article . . . . . .

No. 41. Koenig's Description of the Reis. From *Koenig's Catalogue des Appareils d'Acoustique*, Paris, 1865, p. 5 . . . . . .

No. 42. Pisko. *Die neuren Apparate der Akustik*, Vienna, 1865, pp. 94 *et seq.*

No. 43. Pisko. *Die neuren Apparate der Akustik*, Vienna, 1865, p. 241. The Reis Prospectus . . . . . .

No. 44. *Handbuch der Angewandten Elektricitätslehre*, Von Karl Kuhn, 1865, pp. 1017-21 . . . . . .

No. 45. Hessler's Description of Reis. Hessler's *Lehrburch der technischen Physik* (Technical Paysics), Vienna, 1866, vol. 1, p. 648 . . . .

No. 46. Albert's Catalogue of 1866. *Catalogue of J. Wilh. Albert*, Mechanician at Frankfort-on-the-Main, 1866 . . . . . .

No. 47. "*Electricity*," by Robert M. Ferguson, Edinburgh and London, 1867, p. 257 . . . . . .

No. 48. *Lehrbuch der Physik und Meteorologie* (Text-book of Physics). *Von Joh. Müller. Siebente Auflage, Zweiter Band.* 1868, pp. 386-389 . .

No. 49. *The Manufacturer and Builder*, May, 1869, vol. 1, Nov. 5, pp. 129, 130. Article by Dr. Van der Weyde . . . . . .

No. 50. *The Telegrapher*, vol. 5, No. 39, New York, 1869. [Reprint of Van der Weyde's Article] . . . . . .

No. 51. American Association on Reis. Paper read by Dr. Van der Weyde at meeting of the American Association for the Advancement of Science, at Salem, August, 1869 . . . . . .

No. 52. *Boston Daily Advertiser*, Aug. 25, 1869. Notice of the foregoing meeting . . . . . .

No. 53. *The Wonders of Electricity.* Translated from the French of J. Baile. New York: Scribner, Armstrong & Co., 1872; pp. 140-143 . .

No. 54. Zöllner's *Das Buch der Erfindungen, Gewerbe und Industrien* (Book of Inventions, Trades and Industries); Leipsic, 1872 . . . .

No. 55. Albert's Catalogue of 1873 . . . . . .

No. 56. Wiedemann's *Die Lehre vom Galvanismus*, 1874, vol. 2, pages 598, 599 . . . . . .

No. 57. *Scientific American*, March 4, 1876, Dr. Van der Weyde's second article . . . . . .

No. 58. Official report of exhibition at *South Kensington Museum* in 1876, edited by Dr. Rudolf Biedermann, published in 1877. Notice of the Reis apparatus exhibited . . . . . .

ARTICLES ABOUT REIS AFTER THE BELL PATENT, AND BEFORE THE MICROPHONE WAS KNOWN.

No. 59. Preece on Reis. *Report of the Forty-seventh Meeting of the British Association for the Advancement of Science, held at Plymouth, in August,* 1877. *On the Telephone, by* W. H. PREECE, Memb. Inst. C. E etc. .

No. 60, Ganot's Description of Reis. *Ganot's Elementary Treatise on Physics*, 8th edition, translated by E. Atkinson, N. Y., 1877, p. 757 .

No. 61. Dolbear on Reis. *The Telephone*, by Prof. A. E. Dolbear; Boston, Lee & Shepard, 1877, pp. 99-116 . . . . . .

Defendants' counsel waives proof as to the authenticity of the several Reis and Bourseul publications above named, and as to the correctness of the translations of the same as offered in evidence; but

reserves his right to offer rebutting evidence, both as to the fact of such publications, and as to the correctness of the said translations or of any of them.

Defendants' counsel objects to the introduction of any and all of the above-named publications relating to or making mention of the Reis Telephone except those which appear to have been made by Reis himself, or with his sanction; the ground of his objection being that neither the nature of Reis's invention nor the proper interpretation of Reis's descriptions of the same can properly be ascertained from accounts of others whose qualifications to form a correct and reliable judgment in the premises are not proved or known, and who are not produced for cross-examination in regard to what they have written, and who in material respects may, and in some instances, it is believed, have, changed their views of the Reis invention since the dates of the respective publications hereby objected to.]

Int. 434. Referring to your answer and Cross-int. 180, do you find in the Reis publications therein referred to, or in any other of the Reis publications now put in evidence, any description or suggestions which, according to your understanding of the language employed, indicates that breaks occur at any of the minor vibrations of the diaphragm or electrodes corresponding to overtones, and occurring within the periodic limits of a full vibration corresponding to the fundamental; that is to say, referring to the graphical representation of the form of vibration of the diaphragm, do you understand that either of these Reis publications describes or suggests that breaks occur in the sinuosities of the curve, as contradistinguished from the break which takes place at each periodic recurrence of the curve itself as a whole?

Ans. I do not find in the Reis publications any statement or suggestion which I understand to point out that breaks are to occur corresponding to the overtones. I understand the operation, as described, to consist in the production of a break corresponding to the recurrence of a similar phase in the full or complete vibration.

Int. 435. In your answers to Cross-Int. 161 and Cross-Int. 205, you refer to the theoretical operation of the Reis transmitter in producing electrical variations due to variations in pressure between the electrodes during such time between breaks as the elec-

trodes remain in contact. What practical significance have these theoretical variations in the electrical current, as compared with the changes therein produced by the breaks, and as compared with the operation of the instrument as a whole?

Ans. These theoretical variations are of no practical importance, since the sound due to the breaks masks any minor variations due to microphonic action.

Int. 436. Is there anything in the Reis publications which describes, suggests or indicates that any such microphonic action takes places in the Reis transmitter between breaks, or any language which indicates to your mind that the writers of the same were aware of any such operation?

[*Objected to as leading.*]

Ans. There is not.

Int. 437. In your answers to Cross-Ints. 285, 286, 287 and 288, you considered the effect of altering the Reis transmitter by substituting carbon for one of the platinum electrodes, and a metallic diaphragm for the membranous diaphragm. Did you in those answers have in mind any particular form of receiver which you assumed to be used with such altered transmitter?

Ans. I was not particularly considering the form of receiver which was to be used, but tacitly assumed the knitting needle in those answers which bore upon the use of the instrument practically and commercially. That is in the answers to Cross-Ints. 286, 287 and 288.

Int. 438. And how did you assume in those answers that the Reis apparatus, so altered, was to be used?

Ans. I assumed that the transmitter was to be used as a microphone, and not as a circuit-breaker.

Int. 439. In the experiments of Prof. E. W. Blake, to which you have referred in your direct examination, and also in answer to Cross-Ints. 254-264, was the diaphragm whose vibrations were recorded entirely unencumbered, or did it have to move a mass which was comparable with the electrodes of the ordinary microphone transmitter, such, for instance, as the Blake transmitter?

Ans. The diaphragm had to move a mirror of steel, to which it

was connected by a stiff steel wire, so that the mass put in motion by the vibrating diaphragm was considerable.

Int. 440. At the close of your answer to Cross-int. 259 you were requested to refer to the original article by Prof. Blake, to ascertain in what tone his apparatus was spoken to. Have you that article here present; and if so, will you state what information it gives upon this subject?

Ans. I have the article here. Prof. Blake writes as follows:—

"With an ordinary tone of voice an amplitude of nearly an inch is obtained, implying a movement of the centre of the disk of .005 inches as determined by actual measurement."

Int. 441. In your answers to Cross-Ints. 419–421, you refer to certain experiments, testified about in the Ghegan case, with a break wheel placed in a magneto telephone circuit. Will you here introduce your testimony on this subject in the Ghegan case, and state whether the facts and opinions therein contained are in accordance with your present recollection and opinion?

[*Question objected to as leading; and also because the testimony of the witness, as given in the Ghegan case, and referred to in the question, appears to defendants' counsel to misrepresent some parts of Prof. Mayer's affidavit. If the testimony is to be used at all, it should be in connection with the said affidavit of Prof. Mayer.*]

Ans. My testimony in the Ghegan case on the subject is as follows:

31. A statement in Prof. Mayer's first affidavit, filed by the defendant on the motion for preliminary injunction, expresses the opinion that speech may be transmitted through a circuit in which occur *some* breaks, causing *some* interruptions in the current. Assuming this to be true, either as here generally stated or as read in the light of the specific facts and experiments which follow in Prof. Mayer's affidavit, I am of opinion that it would not in any way relieve the apparatus from the charge of employing Mr. Bell's method in its transmission of speech, in spite of such interruptions.

32. Prof. Mayer follows this opinion by the statement (p. 2), "The experiment on which I formed the above opinion is as follows." He then describes his experiment, from which it appears that his opinion is a statement of the following fact: A magneto transmitter and receiver are connected together in direct circuit, as usual, and speech is transmitted. The voice acting on that transmitter causes

electrical undulations similar in form to the sound-waves, and the speech is transmitted by means of them. This I do not understand to be disputed. A break wheel is then introduced into the circuit, and from time to time interrupts all communication between transmitter and receiver. While the line wire is thus interrupted, the electrical undulations, though still caused at the transmitter, do not pass. When these breaks have a certain (very brief) length, speech is entirely prevented; but when the interrupting apparatus is so operated that no one break exceeds in duration $\frac{1}{1200}$ or $\frac{1}{1600}$ (or $\frac{1}{600}$ or $\frac{1}{800}$, I am not sure which) of a second, speech can be intelligibly transmitted. It is obvious that the speech is then transmitted, not by what is lost but by what remains; and the experiment only shows that the electrical undulations are so perfect a means for attaining the desired end that even when many of these losses occur, if each one is very brief, the undulations that remain will still accomplish it to an extent practically useful.

33. I have several times performed a similar experiment, both before and since Prof. Mayer's affidavit was filed, using in a circuit which did not include a battery two of the break wheels described in my former affidavit, and also one like his; with the one like his I ran the speed up to 900 makes and 900 breaks a second. While such breaks in a magneto circuit do not prevent speech, they produce a characteristic sound which is noticed by the ear as an annoying or disagreeable disturbance. Prof. Mayer does not state what he found in this respect.

34. But the conditions of this experiment are widely different from those present in the battery circuit which includes the defendant's microphone, and it has no tendency to show that that instrument does in fact break, nor that frequent breaks in a *battery* circuit are consistent with the transmission of speech. It has already been stated that an interruption causes two evils: first, it stops out part of the electrical undulations; and the experiment of Prof. Mayer shows that when each stop exceeds the small duration stated, speech is for that reason destroyed. But when the interruption takes place in a circuit which includes a battery, it acts to let on and shut off abruptly the whole force of the battery, which is vastly greater than that portion of the force which is used to make speech, and thus to give a violent electrical, magnetic and sonorous shock to the acting parts of the apparatus, and so to produce a loud and comparatively overpowering sound. It is for this reason, as stated in the former affidavits, that the interruption of a *battery* circuit, though only for $\frac{1}{24000}$ of a second, produces such an effect that if repeated about forty times a second, it drowns out speech. The defendant's transmitter, like all microphones, is always and necessarily included in a battery circuit, and if it breaks the circuit it interrupts a *battery* current; such an interruption at each vibration is absolutely destructive of speech. The experiment of Prof. Mayer has no tendency to

show to the contrary. Indeed, it is so arranged as to entirely avoid the fatal difficulty which is necessarily attached to breaks in the defendant's transmitter.

35. I repeated the experiment of Prof. Mayer, this time including a single cell of battery in the circuit with his break wheel; speech was destroyed, no matter at what velocity the wheel was turned.

The facts and opinions therein contained are in accordance with my present recollection and opinion.

Int. 442. In your answers to Cross-Ints. 156 and 157 you refer to your own trials of the Reis apparatus, and to a former deposition in one of the telephone cases wherein you have stated them more at length. To what telephone case did you refer?

Ans. I referred to the case of the American Bell Telephone Company v. Amos E. Dolbear et al.

[*Counsel for complainants offers in evidence from the printed record in the Dolbear case just referred to, the notes of the stenographic reporters, Messrs. Yerrinton, Barnes, and Leighton; and of the special examiner, Mr. Copeland, relating to the experiments made by the defendants therein with the Reis apparatus, namely, the Reis cubical box transmitter and the Reis knitting-needle receiver in circuit with a battery.*

Defendants' counsel objects to the introduction of the foregoing notes, on the following grounds:

1. *Because the defendants herein had nothing whatever to do with the experiments to which the said notes relate, and can in no respect be bound by the results thereof.*

2. *Because the instrument, Reis receiver No.* 1, *with which a portion of the said experiments were made, was at the time in an imperfect condition, the sounding box being traversed by numerous cracks as fully appears by Prof. Dolbear's answer to Int.* 159 *in the Dolbear case.*

3. *Because the conditions under which the said experiments were made, were not such as, in the judgment of defendants' counsel, were suitable for testing instruments of such extreme delicacy. This sufficiently appears by reference to Prof. Dolbear's answer to Int.* 158 *and Int.* 180. *Int.* 180 *and the answer thereto being as follows:*

"*Int.* 180. Are you prepared to test the matter with this receiver,

Exhibit Reis Receiver No. 2, as you did yesterday afternoon, and also to test both the Reis receivers with some modern transmitter, to see whether the receivers are in working order or not, and test the Reis transmitter with some modern receiver?

"*Ans.* I don't want to do any experimental work when I have to have such such objectionable conditions imposed upon me as were imposed upon me yesterday afternoon."

4. *Because defendants herein have no knowledge in regard to the skill of Mr. Buck, Mr. Eaton and Prof. Dolbear for carrying on experiments of the kind referred to.*

5. *Because, in any event, the particular experiments referred to can have no other effect than to prove the character of the particular instruments with which the experiments were conducted, which, as defendants' counsel understands, were not instruments made by Mr. Reis.*

6. *Because specially it does not appear that the experiments were conducted under the same conditions as regards strength of battery, weight of anvil electrode, character of conductors, etc., etc., as characterized the various experiments made by Mr. Reis with the instruments that he invented and made.*

7. *Because the notes which complainants offer in evidence, constitute only a part of the record of the full experiments made by the defendants in the Dolbear suit, and in which Reis instruments in some form were used. It is believed that the full record should be introduced for a correct understanding of what was proved by the said experiments as to the capacity, even of the identical instruments with which the experiments were conducted.*

Subject to the foregoing objections, defendants' counsel waives formal proof of the said notes, and agrees that they may have the same effect and force as if put in evidence herein by the sworn testimony of the several persons who originally took them.

Counsel for complainants here states to counsel for defendants that if he deems the notes of the other experiments to which he has referred in his seventh objection, to be of any importance in this connection, namely, Experiments with the Reis Transmitter connected up with a modern magneto receiver, either with or without the use of an induction coil; and Experiments with the Reis Receiver connected up in circuit with a modern carbon microphone, complainants' counsel will

waive formal proof of the said notes if defendants' counsel chooses to put them in evidence.]

[*The notes here put in evidence by complainants' counsel are as follows:* —]

BOSTON, May 31, 1883.

NOTES OF MR. YERRINGTON, SHORT-HAND WRITER, AND OF WILLIAU A. COPELAND, *Special Examiner.*

[*Crnditions of the Experiments.*]

Defendants' Exhibit Reis Transmitter is arranged in one of Mr. Maynadier's rooms, and the Exhibit Reis Receiver in another. The two stations are separated by two intervening rooms, the intermediate doors being closed. Present in the transmitting room, Mr. Buck, who made the connections, and who handled, operated and spoke into the instrument; Mr. Maynadier, Mr. Storrow, Prof. Cross, on behalf of complainants, and Mr. Yerrinton, a short-hand writer who took notes of what was said.

In the receiving room, Prof. Dolbear, who listened at defendants' Exhibit Reis Receiver; Mr. Chauncey Smith, of counsel for complainants; and the examiner, who made notes. There was also arranged between the two stations an entirely independent circuit with an ordinary magneto telephone at each end, and called the tell-tale line, merely for convenience of communication between the two rooms. Mr. Chauncey Smith attended to the end of this line in the receiving room, and Mr. Storrow in the transmitting room. The experiment began at 2.45 P. M. and ended about 3.15.

The notes of Mr. Yerrinton in the transmitting room are as follows: —

NOTES BY MR. YERRINTON.

In the transmitting room, defendants' Exhibit *Reis Transmitter*, connected through two large Grenet cells, in direct circuit with the receiver, with a key in the circuit which leaves the battery open when not speaking. In the receiving room the defendants' Exhibit *Reis Receiver No.* 1, Prof. Dolbear listening. Tell-tale line, with a hand magneto at each end, also connects the two rooms. Time, 2.45 P. M.

H. C. Buck at transmitter (speaking into top of instrument): Halloa! one, two, three, four, five. Do you get that? One, two, three, four, five — one, two, three. How do you get that? To be or not to be, that is the question. One, two, three, four, five — one, two, three, four, five, six, seven, eight, nine, ten. How do you get that?

(Speaking into mouthpiece): One, two, three, four, five — one two, three, four, five — one, two, three, four, five. How do you get that? Mary had a little lamb, its fleece was white as snow, and everywhere that Mary went, that lamb was sure to go. To be or not to be, that is the question. One, two, three, four, five — one, two, three, four, five — one, two, three, four, five — one, two, three, four, five, six. How do you get that; One, two, three, four, five, six, seven, eight, nine, ten — one, two, three, four, five, six, seven, eight, nine, ten — one, two, three, four, five, six, seven, eight. How do you get that? Mary had a little lamb, its fleece was white as snow, and everywhere that Mary went, that lamb was sure to go. One, two, three, four, five — one, two, three, four, five — one, two, three, four, five. How do you get that? One, two, three, four, five, six, seven, eight, nine, ten. There was a little girl, and she had a little curl, right in the middle of her forehead; and when she was good, she was very, very good, but when she was bad she was horrid. One, two, three, four, five — one, two, three, four, five. How do you get that? To be or not to be, that is the question. Green clouds in air suspended. Steamers arrived in Boston, May 30. New York, Cincinnati, Glasgow, London. How do you get that? One, two, three, four, five, six, seven, eight, nine, ten.

[Mr. Maynadier (to Mr. Storrow at the telltale line): Won't you ask Mr. Smith [who is in the receiving room] whether Prof. Dolbear has heard anything through there or not? We want to know what the result is there.

Mr. Storrow (through the telltale line to Mr. Smith): Halloa! What have you heard? Mr. Smith answers that they have heard some counting, and "How did you get that? How did you get that?" (To Mr. Buck): Stop a little between each sentence, — not so fast. Suppose you speak your sentences into the mouthpiece, not against the top. Take anything out of the newspaper. Don't take common, familiar sentences. Anybody operating a telephone can guess those.]

Mr. Buck (speaking into the mouthpiece): The royal march and Bavarian hymn announced the arrival of the royal family. The royal hymn announced the arrival of the royal family. The royal hymn announced the arrival of the royal family. How do you get that? One, two, three, four, five. The prince looked very handsome in his costume of blue velvet satin. A, B, C, D, E, F. G. How do you get that? The Bavarian national air. Carts were pressed into service on the New York side as they arrived, and the dead and injured were hurriedly driven out to the City Hall, where they were laid in the police station in the basement. Latest ship news. Halifax, May 30, 1883. It was not found. It was said that a man had been seen carrying a dead baby away, but the police had no account of it.

[Mr. STORROW (through the telltale line to Mr. Smith): Halloa! Yes, we have been talking away for five minutes. Wait a moment. What? We have just lifted the plates out a moment to rest the battery. Now listen.]

Mr. BUCK (into the Reis transmitter): Reports are still coming in of the effects of the storm on Monday. At Freeport the bridge across the river was torn from its piers. One, two, three, four, five, six, seven, eight, nine, ten. How do you get that? One, two, three, four, five. Clothing was scattered about in every direction. More than half a score were dead when extricated from the throbbing heap. How do you get that? Others were more or less terribly injured. They lay eight or ten deep, those in the lower tier long dead. All were hatless, many shoeless, and on others the clothes hung in rags. Five women, all dead and trampled into an unshapely mass, were taken from the bottom of the heap. One, two, three, four, five. Mary had a little lamb. A, B, C, D, E, F, G. To be or not to be, that is the question. One, two, three, four, five, six, seven, eight, nine, ten. How do you get that (six whistles)?

(Speaking in top of instrument): One, two, three, four, five — one, two, three, four, five.

[Mr. BUCK: Do you want me to go on any longer?

Mr. STORROW: Wait a moment, until I go into the other room.

(Mr. Storrow and Prof. Cross left the room, but soon returned.)

Mr. MAYNADIER, There is something the matter with the wire; I reckon that is the trouble.]

Mr. BUCK (*speaking into the mouthpiece*); By three o'clock the crowd in the pleasant grounds surrounding the Hotel Pines numbered nearly 10,000 people. (Speaking into the top): By three o'clock the people in the grounds numbered nearly 10,000. (Speaking into mouthpiece): Many sat on the broad piazzas. (Speaking to the top): Many sat on the broad piazzas. The clear skies promised a fair day. (Speaking in the mouthpiece): The clear skies promised a fair day. (Speaking in the top): The clear skies promised a fair day. (Speaking in the mouthpiece): Rome, Italy, May 17, 1883. (Speaking in the top): Rome, Italy, May 17, 1883. One, two, three, four, five. (Speaking in the mouthpiece): Some of these entertainments were poor and unsuccessful; others superb, and only in Rome could they have occurred. (Speaking in the top): Only in Rome could they have occurred. (Speaking in the mouthpiece): Showery, gusty weather destroyed the effect of the gala entry, illuminations, the curious characteristic art celebration, etc. Destructive fire at Lynchburg, Va. Five persons killed. The property loss $300,000. (Speaking in the top): Five persons killed. (Speaking in the mouthpiece): Lynchburg, Va., May 30, 1883. The most disastrous fire that ever

swept over this city broke out at ten o'clock this morning. (Speaking in the top): The *Daily Virginian* building and fixtures, the Commercial Bank, the large hardware establishment of John Watts, Brothers & Co. Berlin, May 30, 1883. The workman's sick fund bill passed its third reading in the Reichstag to-day. (Speaking in the mouthpiece): In the House of Commons this afternoon the bill empowering the local authorities in Ireland (speaking in the top) to improve the dwellings of laborers passed its third reading. One, two, three, four, five, six, seven, eight, nine, ten. (Speaking in the mouthpiece): From our Rome correspondent. Fêtes in honor of the Duke of Genoa and his bride. (Speaking in the top): Fêtes in honor of the Duke of Genoa and his bride.

[Mr. BUCK: I don't believe it is any use to continue on in this strain.

Mr. MAYNADIER: Something is the matter, I should think. Either the connections are wrong —

Mr. STORROW: The connections seem to be all right.

Mr. MAYNADIER: I think you ought to try some other way.

Mr. STORROW: I don't care for anything more, unless you do.

Mr. BUCK (to Prof. Cross): Would you like to speak here?

Prof. CROSS: I was just going to ask you to send through some irregular numbers, instead of sending through regular numbers. Leave long enough space between them, so he can repeat.]

Mr. BUCK (speaking in the mouthpiece): 5—5—3—8—8—10 1—2—10—4—6—40—32—25—99—32—25—86—55—101—302 508—603—904—201—325—486.

[Mr. STORROW: Halloa! I am going to ask Mr. Buck to sound a note, expecting it will break the circuit. Please listen and see what pitches you get. Halloa! What is it? Ask Mr. Dolbear to listen carefully now, and note the different pitches that he hears. (To Mr. Buck): Speak loud enough to break the circuit, intending to break the circuit.]

Mr. BUCK: Do—mi—sol—do—do.

[Mr. STORROW; Halloa! Did you notice any difference of pitch then? Mr. Smith answers through telltale line that they were not listening.]

Mr. BUCK: Do—mi—sol—do—fa—mi—do.

[Mr. STORROW (to Mr. Smith through the tell tale line): What did you hear then? Answer through telltale line. Mr. Dolbear says he hears sounds of a different pitch. (Mr. Storrow through telltale line): Now listen again, please. Do it over again, please, Mr. Buck.]

Mr. BUCK: Do—mi—sol—do—sol—mi—do.

[Mr. STORROW: What did you hear then? He answers through tell tale line that he again heard sounds of a different pitch. Mr. Maynadier, do you want to try anything more?

Mr. MAYNADIER: No.]

THE NOTES OF MR. COPELAND IN THE RECEIVING ROOM ARE AS FOLLOWS: —

First trial: —

Prof. Dolbear says: I heard him say, "One, two, three, four, five, six, seven."

I also heard him say, "How do you get that?"

Some of the numbers I did not hear. I only inferred.

I heard him say, "One, two, three, four, five."

I heard him say, "That."

I heard him count the whole ten, plain.

I heard him count five very plain, in a low tone of voice.

I heard him say, "How do you get that," after counting five.

[Mr. Smith says into the telltale line that Prof. Dolbear heard counting and "How do you get that?"

Prof. Dolbear says: "I thought he said, one, two, three, forty. I don't hear anything now but a make and break."

[During the experiment Prof. Dolbear pressed the instrument close to one ear and closed the other.]

Another trial. [3.05 o'clock.] Prof. Dolbear says:

I heard him say, "One, two, three, four, five," easy.

I heard him say, "One, two, three, four, five, six, seven."

I heard him say, "Mary had a little lamb."

I heard him say, "Mary had a little."

I heard him say, "Mary had a little lamb," again.

I heard him say so again.

They are not transmitting anything.

[3.12.] Six minutes since starting this trial.

Another trial. [3.15.]

I hear sounds of different pitch.

I hear sounds of different pitch when it is at my ear, but which sounds have but little difference of pitch at some little distance from the ear.

BOSTON, June 2, 1883.

NOTES OF MR. BARNES, SHORTHAND WRITER, AT THE TRANSMITTING ROOM.

Transmitting Station: Present, Mr. Maynadier, Mr. Storrow, Prof. Cross, Mr. Eaton, and Mr. Barnes.

At the Receiving Station: Mr. Buck at the receiver, Mr. Chauncey Smith, Mr. Copeland, and Mr. Leighton.

[NOTE.—*The notes of those experiments, in which some instrument other than a Reis transmitter or receiver was used at either end of the line, are put in evidence in a subsequent part of this deposition, and will be found, beginning on p.* , *infra.*]

(*In the transmitting room, Exhibit Reis transmitter, one cell of Grenet battery. In the receiving room, Exhibit Reis Receiver No. 1, the two instruments connected in direct circuit.*)

[Time, 12.10.]

Mr. EATON (speaking at the top): Hullo, Mr. Buck.
It is a cat,
One, two, three, four, five,
How do you like this?
Boston.
One, two, three.
It is a cat.
It is a cat.
It is a cat.
Dog.
D-o-g.
D-o-g.
D-o-g.
Do you hear me?
Do you hear me?
Do you hear me?
Do you hear me?
The horse is four legged.
The horse is four legged.
The horse is four legged.
How is that?
How is that?
Mr. Buck.
That is your name.
That is your name.
[Time, 12.12.]
That is your name.
Do you hear it?
Do you hear it?
Do you hear it?
How does it sound?
How does it sound?
How does it sound?
One, two, three, four.
One, two, three, four.
One, two, three, four.
[Mr. STORROW (telltale line): Hullo, hullo. Listen carefully.]
[Time, 12.14.]
Mr. EATON: Hullo. The May meeting.
The May meeting.
The May meeting.
Ladies night at
Ladies night at

Ladies night at
The Congregational Club.
The Congregational Club.
The Congregational Club.
Dinner and speeches
Dinner and speeches
Dinner and speeches
In Horticultural
In Horticultural
In Horticultural
Hall.
Hall.
Hall.
A paper of English
A paper of English
A paper of English
Congregationalism.
Congregationalism.
Congregationalism.
Opening of the New England
Opening of the New England
Opening of the New England
Woman's suffrage convention.
Woman's suffrage convention.
Woman's suffrage convention.
Business meetings
Business meetings
Business meetings
And so forth.
And so forth.
And so forth.
[Time 12.16.]
June 2, 1883.
June 2, 1883.
June 2, 1883.
It is a dog cart.
It is a dog cart.
It is a dog cart.
Cart.
Cart.
Cart.
How is that?
How is that?
How is it?
The Reis telephone.
The Reis telephone.
The Reis telephone.

The Reis telephone.
[Time 12.17.]
No. 81 Milk Street.
No. 81 Milk Street.
No. 81 Milk Street.
One, two, three.
One, two, three.
One, two, three.
How is that?
How do you get it?
How do you get it?
How do you get it?

[Mr. STORROW (telltale line): Hullo, hullo. Say when you are ready. Hullo, hullo. Say when you are ready. *Reis receiver No. 2* now connected. *Reis transmitter as before.* Yes, we are all ready. Now listen.]

[Time 12.20.]
Mr. EATON: Hullo. One, two, three, four, five.
One, two, three, four, five.
One, two, three, four, five.
How is that?
How is that?
How is that?
May fifth.
May fifth.
May fifth.
May five times.
May five times.
May five times.
1883.
1883.
1883,
Hullo. Do you get that, Mr. Buck.
It is a dog.
It is a dog.
It is a dog.
What time is it?
What time is it?
What time is it?
New York,
New York,
New York,
Boston,
Boston,
Boston,
Charlestown.
Charlestown.

Charlestown.
Ten, eight, three.
Ten, eight, three.
[Time 12.22.]
[MR. STORROW (telltale line): Hullo. Are you ready?]
Mr. EATON. Choice flower seeds.
Choice flower seeds.
Choice flower seeds.
Flowering plants.
Flowering plants.
Flowering plants.
Trees.
Trees.
Trees.
Shrubs.
Shrubs.
Shrubs.
[Time 12.23.]
Roses.
Roses.
Roses.
Bulbs.
Bulbs.
Bulbs.
Easy lawn mower.
Easy lawn mower.
Parker's choice lawn grass seed.
Parker's choice lawn grass seed.
Parker's choice lawn grass seed.
Lawn house reels,
Lawn house reels,
Lawn house reels,
And hose,
And hose,
And hose.
Lawn seats and vases,
Lawn seats and vases,
Lawn seats and vases,
And lawn fertilizers,
And lawn fertilizers,
And lawn fertilizers,
Parker & Gannett,
Parker & Gannett,
Parker & Gannett,
49 North Market Street,
49 North Market Street,
49 North Market Street,

Boston.
Boston.
Boston.
Gardeners' Guide sent free to all who apply.
Gardeners' Guide sent free to all who apply.
Gardeners' Guide sent free to all who apply.
How is that? All right?
(All the foregoing spoken to the top of the transmitter.)
[Mr. STORROW (telltale line): Hullo hullo. Are you listening? Are you listening? Now listen, please.]
Mr. EATON: Hullo. There will be three sessions to-day.
There will be three sessions to-day.
There will be three sessions to-day.
There will be three sessions to-day.
There will be three sessions to-day.
[Time, 12.26.]
There will be three sessions to-day.
There will be three sessions to-day.
There will be three sessions to-day.
(All this spoken in the mouthpiece.)
The first in the morning.
The first in the morning.
[Mr. STORROW (telltale line): What is it? What is it?]
Mr. EATON: The first in the morning
The first in the morning
The first in the morning
At half-past ten,
At half-past ten,
At half-past ten,
At half-past-ten,
At half-past ten,
At half-past ten,
At half-past ten,
Which will be devoted to business.
Which will be devoted
Which will be devoted
Which will be devoted
Which will be devoted
[Time, 12.27.]
To business.
To business.
To business.
Which will be devoted to business.
(Speaking in the mouthpiece right along.)
In the afternoon
In the afternoon
In the afternoon
In the afternoon

At half-past two,
At half-past two,
At half-past two,
And in the evening,
And in the evening,
And in the evening,
At half-past seven.
At half-past seven.
At half-past seven.
At half-past seven.
Among the speakers
Among the speakers
Among the speakers
Will be Lucy Stone,
Will be Lucy Stone,
Will be Lucy Stone,
Will be Lucy Stone,
Mrs. Mary A. Livermore,
Mrs. Mary A. Livermore,
Mrs. Mary A. Livermore,
Mrs. Mary A. Livermore,
Mrs. Julia Ward
Mrs. Julia Ward
Howe,
Howe,
Howe,
Anna Garland Spencer,
Anna Garland Spencer,
Anna Garland Spencer,
And Miss Lelia Partridge.
And Miss Lelia Partridge.
And Miss Lelia Partridge.
And Miss Lelia Partridge.
How is that, all right?

(This last experiment was in varying tones of voice, high and low, shrill and gruff.)

NOTES OF MR. LEIGHTON, SHORTHAND WRITER, IN RECEIVING ROOM.

Present: Mr. Chauncey Smith, Mr. W. A. Copeland, Mr. Buck, Mr. Leighton.

(*In transmitting room: Exhibit Reis Transmitter, No. 1. One cell. Grenet battery. Direct circuit.*)

Mr. Eaton speaking.

Mr. Buck receiving, with Exhibit *Reis Receiver No. 1*, hears as follows: —

(12.09½) Halloo. 1, 2, 3, 4, 5.
Mr. Buck — 3, 4, 6 — 1, 2, 3, 4.
(12.13½.) Transmitter (I thought I heard the word).
43.
Halloo (12.17½).
Reis transmitter: *Reis Receiver No. 2* as receiver.
Mr. Buck at receiver, hears as follows:
(12.19½) 1, 2, 3, 4, 5 (I wasn't sure of that, though). Boston — Boston.
(I almost hear. It breaks just enough to spoil it.)
Did you hear that? (12.29½.)
(I think the conditions are changed in some way.)

[*Counsel for complainants offers in evidence portions of the deposition of Henry C. Buck, taken from the printed record in the Dolbear case, and relating to the Reis apparatus used by the defendants therein in the experiments referred to in the notes already put in evidence; and it is agreed that the same may stand in this case with the same force and effect as if the said Henry C. Buck was produced as a witness herein and repeated his said testimony under oath. The said testimony is as follows:*]

EXTRACT FROM DEPOSITION OF HENRY C. BUCK, A WITNESS CALLED FOR THE DEFENDANTS IN DOLBEAR'S CASE.

Int. 4. Please state what experience you have had in the use of these three instruments, Exhibits Reis Transmitter, Reis Receiver No. 1 and Reis Receiver No. 2, with the transmitter and one of the receivers in the same circuit; and state, also, how otherwise you have used these exhibits and with what results.

Ans. I, myself, bought in Europe, of the man who said he made them, the above-mentioned transmitter and receiver No. 1, in 1881. They were in exact imitation of those now held by the German Government, and which were claimed to have been an original pair of instruments constructed for Reis. I myself compared these instruments with those original instruments which were exhibited at the International Electrical Exhibition at Paris, in 1881, and found no appreciable difference. I have frequently experimented with those instruments, and also with Receiver No. 2. The greater part of my experiments with these instruments were performed in the laboratory at Tuft's College, that place being selected because comparatively free from noise, and the time was selected when noise was least likely to interfere with our experiments.

To produce the best and most satisfactory effects, favorable conditions are essential.

(N. J. McDONOUGH)

I have frequently connected the Reis transmitter above-mentioned, in a direct circuit with one of the two receivers, and have, perhaps, invariably, been able to hear counting and single words, and occasionally whole sentences, although this is a delicate experiment, and requires absolute freedom from all disturbing influences.

My experiments with these instruments have been varied in a great many ways, and have included many complex combinations, extending over a period of several years.

From these experiments I will briefly describe two or three. I have connected up this Reis transmitter with various receiving telephones in direct circuit, as, for example, a low resistance magneto-receiver. Under these conditions, if the person at the transmitter spoke in a voice of suitable strength, I was able to understand distinctly many sentences, and sometimes have been able to hear and understand nearly, if not all, that was said at the transmitter, thus showing that the Reis transmitter is capable of producing an undulatory current. To produce these results it is desirable that the listener should have means of constantly communicating with the person who is transmitting

I have also frequently connected these Reis receivers, No. 1 and No. 2, in direct circuit with any good modern carbon transmitter, and been able to hear, while listening at the receiver, nearly, if not quite all that was said at the transmitter, this experiment going to show that the Reis receiver is capable of receiving. In this answer I have not referred to the tests which were made in the presence of the examiner and parties, because I did not understand that the question calls for it.

[*Adjourned.*]

BOSTON, June 4, 1883.

Int. 5. In your last answer you say that it is desirable that the listener should have means of constantly communicating with the person who is transmitting. Please explain more fully what you mean by that, and why it is desirable.

Ans. It has been my experience with the several Reis transmitters which I have used — I mean like Exhibit Reis Transmitter in all respects — that each instrument differs from the others in the loudness of tones to which it should be subjected for the best results; also the pitch, — there is a certain pitch best adapted to each instrument. The Reis transmitters will not transmit properly when coupled in direct circuit, unless precautions be taken to maintain a suitable loudness and pitch in the voice of the person transmitting. This is why it is desirable for the listener to be able to give such necessary directions to the person transmitting as to varying the loudness and pitch when producing the best results.

Int. 6. Did you take part in the tests, May 31 and June 2, of the Reis receivers and the Reis transmitter in direct circuit, with

Prof. Dolbear and Mr. Eaton? If so, please explain the main difficulties under which those tests were carried on.

Ans. I did. As I said in the previous answer, it is quite desirable, in experiments with these instruments, that they be performed in a place free from all extraneous noises, both in the room and from the street. While listening at the receiver, during those experiments, there were several persons in the room at all times, some of whom were engaged in writing; and consequently, more or less noise was produced. Moveover, the noise from the street was found to be quite a serious inconvenience while listening at the receiver, although the room may be regarded as in a quiet locality.

In a previous answer I also stated that it is essential that the proper degree of loudness of tone and pitch of the voice be maintained by the speaker while using the Exhibit Reis Transmitter. In all my previous experiments we have had means provided for giving such necessary directions to the persons at the transmitter. During the experiments we were not allowed to have direct communication. If I observed, while listening at the receiver, that the sounds were either too strong or too weak, it was necessary for me to request Mr. Chauncey Smith, who was provided with the telltale line telephone, to inform Mr. Storrow to tell the speaker to speak a little stronger or a little weaker, as the case might be. It generally happened when this was done that the speaker took the other extreme, and the elaborate process had to be repeated. If I simply remarked while listening at the receiver that the speaker was speaking too loud or too weak, no attention was given to the remark by Mr. Smith.

Moreover, when I found by listening at the receiver that the conditions were nearly right for producing a sentence, I often hesitated to make request for a change, because thinking the conditions would the next moment come all right without my interference. I also frequently omitted to report the minor words, lest by so doing the sound produced by my voice should prevent my hearing a complete sentence.

Int. 7. Please state the best results which you personally have obtained with Exhibit Reis Transmitter in direct circuit with Reis receiver No. 1 as compared with the result of the tests last week when those two instruments were used together.

Ans. When I first experimented with Reis receiver No. 1 it was in much better condition than it was during those experiments of last week, since the sounding boards have become cracked and broken in several places. My former experience with receiver No. 1 and No. 2 compared, was that No. 1 receiver produced much clearer tones, but that receiver No. 2 was the louder instrument.

I have heard longer sentences, louder talking, and more distinct enunciation with receiver No. 1 during former experiments than I heard during those of last week. This I take to have been partly

due to the poorer condition of the receiver during these experiments of last week, and partly to the conditions being much less favorable at those times.

DECEMBER 17, 1885.

Int. 443. Were you present at the trials of the Reis apparatus by the defendants in the Dolbear case, and referred to in the notes of Messrs. Yerrinton, Barnes, Leighton, and Copeland, which have been put in evidence in this case, and did you observe the conditions under which those instruments were then tried?

Ans. I was present, and did observe the conditions regarding which you inquire.

Int. 444. What reasonable grounds, if any, in your judgment, did Mr. Dolbear have for objecting to the conditions imposed upon him during the trials of May 31, 1883, as mentioned in his answer to Int. 180, which counsel for defendants has quoted?

[*Objected to as incompetent.*]

Ans. So far as I know, there were no reasonable grounds for Mr. Dolbear's objection referred to. The place, instruments used, arrangement of the circuit, operators, and manner of conducting the tests, were chosen by Mr. Dolbear and those associated with him. I heard no objection at the time of the tests from Mr. Dolbear or his associates; and at the conclusion of the tests, though before the reports of the stenographers and others in the transmitting and receiving rooms were compared, Mr. Dolbear appeared to be satisfied with the results. This was the impression which I gained from what was said at the time by Mr. Dolbear himself. The gentlemen who spoke to the transmitter had voices well suited to the purpose, and it was evident that they understood the conditions to be observed in tests of that nature.

Int. 445. Did you examine the instruments Exhibit Reis Transmitter, Exhibit Reis Receiver No. 1 and Exhibit Reis Receiver No. 2, used in those tests of May 31 and June 2, 1883, and, if so, what have you to say in respect to their physical conditions at the time?

Ans. I did examine those exhibits at the time. As I remember them, they were all in excellent condition except that Receiver No. 1 had its removable cover cracked. I remember gaining the impression at the time, from what was said by Prof. Dolbear, that this instrument, notwithstanding the seeming defect, was preferred by him to the other receiver.

Int. 446. Will you read from the Dolbear case the testimony which you gave in relation to the experiments of the defendants therein, and with reference to the Reis apparatus; and state whether the facts set forth in your said testimony are true?

Ans. The facts therein stated are true. I read them from my deposition as follows: —

"Testimony of Prof. Charles R. Cross, given in Dolbear's case.

Int. 8. Have you read the publications by and relating to Reis which have been put in evidence by the defendants, and also those which have been put in evidence by the complainants?

Ans. I have done so.

Int. 9. Will you state whether the intention of Reis, as expressed by himself and others in their publications, was that his apparatus, when in use, should interrupt the current with a frequency corresponding to the pitch of the sound which actuated the transmitter, or whether it was that it should merely vary the current without ever interrupting it?

[*Objected to because a variation of the current by increasing the resistance seems to the defendants' counsel* [*in the Dolbear case*] *one form of interrupting the current.*]

Ans. The intention of Reis, as stated in the various authoritative publications regarding his apparatus, was that the current should be interrupted — that is, reduced to zero — once for each vibration of the membrane, in correspondence with the pitch of the sound acting upon the membrane, so that the strength of the current should vary intermittently from a finite quantity to zero.

Int. 10. Considering the mechanical action of the two electrodes in the various forms of the Reis apparatus shown in the publications, do those publications state the intention to be that the two electrodes should part company with a frequency corresponding with the pitch of the sound which actuated the membrane, or do they state the intention to be that they should never part company, but always remain in contact?

[*Objected to* [*by counsel for defendants in the Dolbear case*] *as not within the province of the witness.*]

Ans. The publications state distinctly that the intention is that the two electrodes shall be separated from each other and again brought into contact with a frequency corresponding with the pitch of the sound actuating the membrane.

Int. 11. Turning now to those portions of the publications which purport to state the facts learned by actual use and observation of the Reis transmitter when in action, do they state that in actual operation the electrodes do part company and interrupt the electric current, or do they state that in fact they do not part company and do not interrupt the current?

Ans. They state that, as a matter of fact, in the operation of the instrument the electrodes do part company and so interrupt the current.

Int. 12. In several places in his deposition, particularly on pages 379 and 426, Prof. Dolbear undertakes to draw a distinction between breaking the contact and interrupting the current, and intimates that a statement that the contact was broken would not necessarily imply that the current was interrupted. Will you tell me whether, in the Reis publications, the precise phrase used to express the action of the apparatus upon the current is "breaking the contact," or whether it is, "interrupting the current"?

[*Objected to, as the intimation set forth is not, in the opinion of defendants' counsel* [*in the Dolbear case*], *found anywhere in Prof. Dolbear's deposition.*

Complainants quote from page 379: "*A distinction must, therefore, be kept in mind between a* break of contact *and a* break in current. *A* break of contact *does not imply a* break in current."]

Ans. The statement made in the Reis publications as to the operation of the apparatus in the original German is, that the *current* is *broken*, not simply that there is a break of *contact* or an interruption in the *circuit*.

Int. 13. If, in those parts of the publications which purport to state what was observed in the actual use and observation of the Reis apparatus when in action, you find stated any observed facts which go to show whether the apparatus did habitually break the current in the manner stated, will you please to mention some of those facts?

Ans. The transmitting apparatus of Reis is described as showing a spark at the contact points of the electrodes when the apparatus was in operation. The production of this spark is an evidence that the electrodes have parted contact. Also a rattling sound is described as proceeding from the electrodes, which indicates a parting of contact. Still further, the sound produced by the Reis receiver, is described as being audible throughout a large room. This could happen only when the transmitter operated by breaking the circuit.

Int. 14. It appears from the statements in the Reis publications, and from the measurements introduced in evidence yesterday by the defendants' witness, Mr. Eaton, that the circuit employed by the various writers referred to employed a moderate length of line wire, three cores with coils inside them, the total resistance of the three being between three and four ohms, and two or three cells of battery, and a transmitter. In such an apparatus, would breaking the contact of the electrodes sufficiently to interrupt the battery current produce a spark at the break; and would a visible spark be there produced without interrupting the battery current?

Ans. A visible spark would not be produced by this apparatus unless the battery current was interrupted; and an interruption of

the battery current would generally, and probably always, produce a spark.

Int. 15. If the apparatus operated in the manner described in the various publications, as stated in your previous answers, would it, when so operated, transmit articulate speech?

Ans. It would not.

Int. 16. It has appeared that the hopping electrode of the *Reis transmitter* weighs about seventeen grains, and that in the modern articulating microphones produced, the electrode not attached to the diaphragm weighs from seventy-five to four hundred and sixty-five grains.

Will you tell me whether this marked difference in physical structure adapts the one instrument to break the circuit and interrupt the current, and the other to vary the current without interrupting it, when the same voice is applied to vibrate the diaphragms of both; and which structure is adapted for one purpose, and which for the other, and give your reasons?

Ans. The difference in structure referred to in your question is a matter of great importance. If the electrodes when actuated by the voice are to part company and so interrupt the current, they should be, and as a matter of fact, always have been made light, and caused to rest lightly upon each other.

This being the case, the impulse given by the vibrations of the voice will be sufficient to throw them out of contact with each other and thus secure the desired breaking of the circuit.

On the other hand, if the instrument is to be used as a variable resistance battery transmitter for the transmission of articulate speech, in which case the current must be simply varied and never interrupted, the electrode which is not attached to the diaphragm or immediately actuated by the motions of the diaphragm should be, and practically is given a considerable mass, in which case it is much more difficult to break the contact of the electrodes than if the second or anvil electrode has a less mass, while the variations in the pressure between the two electrodes, which are essential in the operation of such a transmitter, will be much greater, other things being the same, than if the anvil-electrode were lighter.

The reason of this is as follows: The electrode which is attached to, or in contact with the diaphragm, the hammer-electrode, as I will call it, presses more or less lightly against the anvil-electrode, under the normal adjustment of the instrument when the instrument is not in operation. On speaking against the diaphragm, motion is first communicated to the hammer-electrode. As this moves forward, it of course tends to set the anvil-electrode in motion.

The larger the mass of the anvil-electrode the more slowly can any given velocity be imparted to it, and hence there will be an increased pressure between the two electrodes which, other things remaining the same, will be greater with a heavier anvil-electrode

than with a lighter one. Similar actions occur in other portions of the vibration of the hammer-electrode. The mechanical resistance to rapid change of velocity in the anvil-electrode may be called "inertia resistance."

This same inertia of the anvil-electrode which prevents its acquiring rapidly the full velocity of the hammer-electrode also tends to prevent its moving away from the latter and so breaking the contact.

Int. 17. Please examine Mr. Dolbear's seventy-sixth cross-answer, page 405, which gives the weights concerning the anvil-electrode in Exhibit Dolbear Transmitter; his answer to Cross-Int. 155, page 430, which gives the corresponding weights in the Reis transmitter; Mr. Buck's thirteenth cross-answer, page 483, which gives it in the carbon microphone used in some of the defendants' experiments of June 2; and using your own knowledge of the weight of the anvil-electrode in the Blake transmitter, and of the structure, form and arrangement of the anvil-electrodes in these several instruments, state approximately in terms of weight what you have termed the "insertia resistance" of the anvil-electrodes in these several instruments.

Ans. I have used the term "insertia resistance" to indicate the mechanical resistance which occurs when one moving body exerts pressure upon another, thus tending to increase the velocity of the latter. If the second body acquires a simple motion of translation, or a motion which is practically a simple motion of translation, other things remaining the same, the resistance to change of motion will be immediately dependent upon its mass, and may consequently be measured by its weight.

If the motion impressed upon the second body is partly or wholly a motion of rotation (as in the case of a bar pivoted at one end and moved by the application of a force at the other end), the distribution of the mass of the body, as well as the amount of the mass itself, is influential in determining that resistance. It is evident that in any case the resistance to motion at any moment of a mass which must move with a rotary motion, will be equal to the resistance which some determinable mass would offer when acted upon by the same moving force, and that the weight of such a mass may be used to measure this resistance. It is to such a mass, as measured by its weight, that I apply the term "inertia resistance."

In the Blake transmitter the weight of the anvil-electrode is seventy-five grains, and as the motions of the different portions of the electrode are so nearly identical, this will represent very closely its inertia resistance.

In the pendulum carbon microphone used in the experiments of June 2, the weight of the electrode, as in the case of the Blake transmitter, and for the same reason, very closely represents its inertia resistance. This weight is 367.7 grains.

In the Reis transmitter the weight of the hopping piece is sixteen and two tenths grains, and its pressure against the lower electrode

eight and five tenths grains. The insertia resistance is, perhaps, ten grains.

In the case of the Dolbear transmitting apparatus, the weight of the electrode is four hundred and sixty-five grains, and the pressure between the electrodes, fifty-seven grains. The shape of the electrode with its heavy horizontal bar at the end of two supporting pins, which themselves are quite long, gives it a very considerable inertia resistance, which is from seventy-five to one hundred grains.

Of course the effect of this bar is not to add sensibly to the pressure between the electrodes, since it rests directly over the supporting pins, and unless it tilts slightly to one side, it does not affect the pressure between the electrodes at all.

Since, however, this bar is at some distance above the points of support, about which it rotates when set in motion by the hammer electrode, the resistance to motion or inertia resistance is very considerable in proportion to the pressure between the two electrodes.

The inertia resistance of these several instruments can be stated approximately as follows :—

Reis, say, ten grains.

Blake, say, seventy-five grains.

Dolbear transmitter, say, seventy-five to one hundred grains.

'The pendulum microphone, say, —

Int. 18. Please state whether it is or is not the practice with instruments composed of a diaphragm and free anvil-electrode, which are intended to produce in the current articulating undulations without interruptions, to construct the anvil-electrode with such weight and form as to give to it a notable inertia resistance.

Ans. It is the universal practice to do this.

[*Noon recess.*]

Int. 10. Referring now to the physical structure of the *Reis receiver*, is it an instrument which is calculated to give forth fairly audible sounds under variations of current which are exceedingly delicate as compared with current interruption produced in a circuit of moderate resistance and containing one or two cells of battery?

Ans. The Reis receiver produces, and is adapted to produce, only very feeble sounds when the current passing through it has its strength simply varied without actually breaking the circuit.

Int. 20. In the tests which the defendants made on May 31 and June 2, by applying to the Reis receiver what were, or what they claimed to be, undulatory currents as distinguished from intermittent currents, the listener applied the receiver closely to his ear. Do you find in the Reis publications any direction that it should be so applied, or any statement that it was so applied?

Ans. I find no such direction or statement in any publications referred to.

Int. 21. In Prof. Dolbear's deposition, answer 39, page 384, he states that the Reis receiver was an instrument made "to sit upon a

table like an ordinary telegraph instrument, as if Reis expected that the sounds produced by it might be loud enough to be heard by a room full of people." Does that statement substantially conform to the statements in the Reis publications, both the earlier and the later ones?

Ans. It does.

Int. 22. When the Reis receiver is placed upon a table and actuated by a Reis transmitter operated to break the circuit, with a frequency corresponding to the pitch of the sound actuating it, will such receiver produce a sound loud enough to be heard by the by-standers?

Ans. It will.

Int. 23. When laid upon the table and connected with a Reis transmitter, operated so gently as not to interrupt the circuit, will the receiver produce sounds loud enough to be heard by the by-standers?

Ans. It will not.

Int. 24. Assuming that the Reis transmitter, as a structure, is to-day capable of producing to some extent electrical undulations similar in form to the sound waves, in the hands of those who have learned what was taught by Mr. Bell's patent and by the subsequent invention of the articulating microphone transmitter, will you state whether you find in any of the Reis publications any statement that it was desirable to produce such undulations, as distinguished from interruptions, as the means for transmitting speech or other sounds?

Ans. I find no such statement in any of the Reis publications.

Int. 25. Tell me whether you find, in any of those publications, any statement that electrical undulations similar in form to the actuating sound waves *could* be produced by the Reis transmitter.

Ans. I find no such statement whatever.

Int. 26. Do you find in any of the publications made by Reis, himself, anything which shows that he understood that difference in "form" between vibrations which gives to each sound its quality, as you have explained in your first affidavit.

Ans. I do not find in any of Reis's papers any statement showing that he understood the nature of musical quality.

He apparently had only the indefinite ideas which were popularly current when he wrote.

Int. 27. There have been put in evidence extracts from the catalogues of J. W. Albert, the mechanician, who at Frankfurt, a/M., manufactured and sold for Reis his telephone apparatus. One of these catalogues is for 1866 and the other for 1873. Each of them in connection with the telephone of Reis refers to certain books. Will you tell me what those books are, and whether the references are to passages that have been put in evidence?

Ans. The references in the catalogue of 1866 are to Müller-

Pouillet's "Text-book of Physics," sixth edition, Figs. 325–327, and to Pisko's new acoustic apparatus, Fig. 60.

The references in the catalogue of 1873 are to Müller-Pouillet, seventh edition, Figs. 548–550, and to Pisko, Fig. 60.

The passages as referred to in the catalogue of 1873 have been put in evidence in this case. The catalogue of 1866 refers to the same passage in Pisko, and apparently to the same passage in Müller-Pouillet.

Int. 28. When sounds of varying pitches within a moderate range of pitch are sung into the mouthpiece of the Reis transmitter so that it operates to interrupt the currents with a frequency corresponding to the pitch, as stated in the Reis publications, is there or is there not any difficulty in hearing sounds of a corresponding pitch in the Reis receiver connected therewith?

[Objected to by counsel for defendants in the Dolbear case] because it is physically impossible to operate the Reis transmitter in the manner suggested in the question.

Ans. There is not.

Int. 29. Did you attend the tests of the Reis exhibits, which the defendants made on May 31 and June 2 last week, and which are reported in Prof. Dolbear's deposition, pages 434–439 and 449–473.

Ans. I did.

Int. 30. Near the close of the test, on May 31, notes of various pitches were sung into the mouthpiece of the transmitter, and were plainly heard, and the differences of pitch recognized by the listener. Do you remember that particular experiment?

Ans. I do. It is stated on pages 438, 439, *supra*.

Int. 31. Did you, while that particular experiment was going on, carefully watch the electrodes of the transmitter; and if so, what did you observe showing that the battery current was or was not interrupted?

Ans. I watched the electrodes of the transmitter very carefully while this experiment was in progress, and noticed a continuous series of sparks while the notes were sung, showing, evidently, that the instrument was operating as a circuit-breaker.

Int. 32. I have asked you from the reports of those tests introduced in Prof. Dolbear's deposition, aided by your own notes and recollection, to prepare a brief memorandum of what was accomplished during the attempts which the defendants made to transmit articulate speech with the Exhibit Reis Transmitter and the two Exhibits Reis Receiver No. 1 and Reis Receiver No. 2, which the defendants made May 31 and June 2. If you have done so, will you read it as a part of your answer?

Ans. I have [illegible] is as follows:

The results [illegible]

31 was [illegible]

The test occupied twenty-five minutes. Mr. Buck spoke into the Reis transmitter, and Prof. Dolbear listened at the Reis receiver.

Many familiar phrases and many newspaper sentences were spoken; regular numbers, one to five and one to ten, were counted; irregular numbers were counted.

The regular series was repeated thirty times; Prof. Dolbear heard them twice.

"How do you get that?" was repeated fourteen times; Prof. Dolbear heard it twice.

Prof. Dolbear heard, "Mary had a little lamb," three times, and "Mary had a little" once. At the time when he thought he heard these words, no such phrase was uttered into the transmitter. This phrase had been spoken before, and was evidently a familiar one. This is all that was heard during the twenty-five minutes.

During the early part of the experiment the speaking was against the top of the transmitter. This is more likely to produce articulating currents without breaks than speaking into the mouthpiece is, and I think it was during this time that the only phrase and words heard correctly were transmitted. The Reis publications direct that the sounds should be made into the mouthpiece which is provided for that purpose.

Nearly all the speaking was done with a remarkably even and gentle voice, much below the loudness of ordinary conversation. Such force of voice as is used in ordinary conversation, if the mouth be applied to the mouthpiece, invariably caused breaks, manifested to one watching the transmitter by the well-known circuit-breaking sparks and rattling of the contact pieces.

Upon sounding into the mouthpiece sustained notes of different pitches, the circuit-breaking sparks were observed, and the different pitches plainly heard at the receiver.

The result on June 2 was as follows: —

Mr. Buck listened at *Reis receiver No.* 1; Mr. Eaton spoke to the *Reis transmitter*. The voice of the speaker was carefully modulated and gentle, below the tone of ordinary conversation, as on the previous day,

The experiment with *Reis transmitter*, coupled with *Reis receiver No.* 1, lasted eight minutes. Mr. Buck heard as follows: —

"Hallo," which was spoken.

"1, 2, 3, 4, 5," which was spoken.

"Mr. Buck," which was spoken.

"3, 4, 6," which was *not* spoken.

"1, 2, 3, 4," which was spoken three times.

"Transmitter" (he thought); it was *not* spoken.

"Hallo," which was *not* spoken at this time.

With *Reis transmitter*, coupled with *Reis receiver No.* 2, the experiments lasted ten minutes. Mr. Buck heard as follows: —

"1, 2, 3, 4, 5," saying that he wasn't sure of it.

This series was spoken several times.

"Boston," "Boston," remarking "I almost hear; it breaks just enough to spoil it."

"Did you hear that?" it was *not* spoken.

During this last test the voice was more varied; seldom, however, as loud as in ordinary conversation.

Int. 33. I have asked you to prepare in a similar manner a memorandum of what was accomplished on June 2 by the defendants in their attempts to transmit articulate speech with Exhibit Reis transmitter and the two magneto receivers, No. 9 and No. 10.

Ans. I have done [so], and it is as follows: —

Reis Transmitter and Magneto Receiver No. 9.

Mr. Eaton speaking to transmitter; Mr. Buck listening at receiver.

Time, 10.50–10.54. Mr. Buck thought he heard twenty words. Of these the phrase "Do you understand what I say?" was not spoken. 10.55-11.07. Part of what Mr. Buck said he heard was not spoken. Of a long newspaper paragraph, Mr. Buck repeated one word, "Mr. Bradlaugh," and said that he "could hear occasionally a word." 11.02½-11.04½. Newspaper paragraph of one hundred and ninety-two words read. Mr. Buck heard correctly detached phrases containing sixteen words, and one phrase of three words, "on every hand," which was not spoken.

Reis Transmitter and Magneto Receiver No. 10.

Operators as before.

Time, 11.10–11.13. Mr. Buck heard as follows: "Hallo, Mr. Buck!" numbers 1 to 10 and "Do you get that all right?" heard correctly. Newspaper paragraph of one hundred and seventy-nine words read. Mr, Buck heard three only.

Same instruments; Mr. Buck transmitting and Mr. Eaton receiving.

During eighteen minutes the only result was as follows: —

11.17–11.35. Several familiar phrases, such as "How do you get that?" "Mary had a little lamb," etc., and regular numbers, 1 to 10, heard correctly.

Mr. Buck then picked out from the newspaper detached phrases of four to six words each, repeating them two to six times each; Mr. Eaton heard some of these correctly. Mr. Buck read some newspaper sentences, of which Mr. Eaton heard only detached words.

The foregoing was all spoken to the top of the transmitter, except one or two phrases.

Int. 34. I have asked you to prepare a similar memorandum as to their attempt to transmit speech with the Reis transmitter arranged in the primary circuit of an induction coil, and the ordinary

magneto receiver of the commercial form, connected in the secondary circuit.

Ans. I have done so, and it is as follows: —

The *Reis transmitter* was arranged in the primary circuit of an *induction coil*, and the ordinary *Bell magneto receiver* of the commercial form, connected in the secondary circuit.

Time, 11.39 to 11.45. Counting, ordinary phrases and some newspaper sentences were uttered into the transmitter.

Some clauses, one complete sentence, and one familiar phrase were heard.

Int. 35. I have asked you to prepare a similar memorandum as to their attempts on June 2 to transmit speech with the ordinary carbon microphone and Reis receivers No. 1 and No. 2.

Ans. I have done so, and it is as follows: —

Next experiment. A very powerful *modern carbon microphone* of Mr. Berliner's pendulum pattern was connected in *direct* circuit with *Reis receiver No.* 2. Mr. Eaton spoke into it quite loud and Mr. Buck listened.

Detached phrases spoken into it and repeated three times were heard with substantial correctness.

Same *transmitter* and *Reis receiver No.* 1. Experiment conducted in the same way, with substantially the same result.

I afterwards tested this transmitter with the ordinary commercial Bell magneto receiver. The volume of tone furnished by this transmitter was so great that the words could be understood when the Bell receiver was held a foot away from the ear, though the quality of the tone was rather poor, as is often the case with loud-speaking transmitters.

Int. 36. Have you ever yourself attempted to transmit speech with a pair of instruments substantially like defendants' Exhibit Reis Transmitter and defendants' Exhibits Reis Receiver No. 1 and No. 2? And if so, state whether the results you obtained were substantially the same as or substantially different from the results obtained by the defendants in the tests of May 31 and June 2.

Ans. I have made such attempts with substantially the same results as those obtained by the defendants in the experiments under consideration. I have sometimes guessed out familiar or expected sentences largely by their rhythm, and sometimes I have imagined that I heard and understood sentences which, on inquiry, I found to be totally different from those spoken into the transmitter. I have never heard an unexpected and unfamiliar sentence transmitted by the instruments.

Int. 37. The defendants' Exhibit Reis-Legat Receiver has, among other deviations from the description in Legat's article, a piece of paper pasted over the pole of each magnet near the armature, and a soft bit of soft rubber placed between one of the poles and the armature. Will you tell me whether that addition is of any value, and if

so, what, in an attempt to operate that instrument by feeble electric undulations and thereby produce speech?

Ans. The addition referred to is of great value, since it enables one to bring the armature much closer to the poles of the electro-magnet without danger of its sticking to them in the case of accidental contact between the armature and the poles.

Int. 38. Would "sticking" interfere with the operation?

Ans. It would, since the armature would not be free to vibrate as it is intended to do.

Int. 39. Is it desirable or important to bring the armature very close to the magnet when the instrument is to be actuated by slight variations of current as distinguished from interruption of current?

Ans. It is very desirable to do this when varying, but not intermittent, currents are used, since the effect of such a varying current upon the armature is greater in proportion as it is nearer to the poles of the magnet.

Int. 40. In his deposition, and particularly in page 358, Prof. Dolbear calls attention to the fact that in his receiver the pull between the flexible diaphragm next the ear and the substantially rigid plate or mass behind it varies inversely as the square of the distance. Will you tell me whether or not in the apparatus Fig. 7 of Mr. Bell's patent of March 7, 1876, the pull between the flexible diaphragm and its attached armature on the one hand, and the substantially rigid core of the electro-magnet on the other, does or does not vary inversely as the square of the distance, when the distance is varied?

Ans. Since the armature of the Bell telephone, as shown in Fig. 7 of the patent referred to, is permanently polarized through its connection with the core of the electro-magnet, the attraction between the armature and this core will vary in the inverse ratio of the square of the distance.

Int. 41. On the same page, Mr. Dolbear refers to the fact that, under theoretical circumstances, the pull between the flexible plate of his receiver and the rigid mass behind it varies as the square of the electro-motive force, and not directly as the electro-motive force. Will you state whether the same law is true of the pull between the diaphragm and its attached armature on the one hand and the electro-magnet on the other, in Mr. Bell's apparatus of Fig. 7?

Ans. The same is true in the receiver of Mr. Bell, as shown in Fig. 7.

Int. 42. To avoid any misapprehension, I will ask you whether, in the various attempts by you or in your presence to transmit articulate sounds by the Reis transmitter and receivers, the operators sought to use the Reis transmitter, and so far as they attained any success at all, did use it so as to preserve a contact between the two electrodes, and thereby produce electrical undulations similar in form to the sound waves such as are described in Mr. Bell's patent, or

whether they sought to use and did use it to produce breaks of contact and interruptions of current, as described in the Reis publications?

Ans. The transmitter was so used as to produce electrical undulations without breaking the circuit, as far as possible.

Cross-Examination by J. E. MAYNADIER, Esq., *of Counsel for Defendants in the Dolbear case.*

Cross-Int. 43. In the great majority of all telephones now in use there is a very short battery circuit with an instrument in it sometimes called a microphone transmitter, and sometimes called a Blake transmitter, and sometimes called a battery transmitter. What, in your opinion, are the substantial differences between such a transmitter and Exhibit Reis Transmitter? Please name all that you believe to be substantial.

Ans. The Blake transmitter has a metallic diaphragm; the Reis instrument has a membrane diaphragm. The Blake transmitter has a narrow space in front of the diaphragm, between it and the mouthpiece; the Reis transmitter has a long speaking tube, and a cubical box between it and the membrane. The Blake transmitter has a heavy anvil-electrode; the Reis apparatus a very light anvil-electrode. The Blake is also furnished with an induction coil, though this is not essential; the Reis has no such induction coil.

In the Blake the rear face of the diaphragm and the electrodes are protected from disturbance due to extraneous vibrations by being completely closed within a box; in the Exhibit Reis Transmitter, these electrodes are open to the air, although from the appearance of the instrument there may have been a glass cover placed over the electrodes.

The Blake transmitter is arranged so that the voice of the speaker acts directly upon the membrane without the intervention of any long speaking tube; in the Reis instrument the speaking tube is several inches long.

Cross-Int. 44. Do you not agree with me that the community is indebted to Reis for the initial step now used in the great majority of all telephonic apparatuses now in use, namely, the control of an electric current by the energy of air waves acting upon a diaphragm, which diphragm acts immediately upon one electrode, through which the current passes, and through that electrode acts upon another electrode, through which the current also passes; and don't you also agree with me that Reis's invention of that method and apparatus is of equal rank, at least, with anything ever accomplished since, in the way of transforming the energy of sound waves into electric energy? If not, please explain why not.

[*Objected to because it is ambiguous in its most important clause, and because it misstates the work and method of Reis as defined by himself and associates.*]

Ans. The apparatus of Reis was certainly a very beautiful toy; but in view of the facts that his apparatus was barren of all useful results, so far as the transmission of speech is concerned; that it is absolutely impossible to transmit speech by the method that he pointed out; that the electric current is not controlled by the energy of the air waves acting upon his diaphragm; that the first electrode acts upon the second electrode in such a manner as to intermittently and for short periods prevent the currents from passing through any portion of the apparatus; and recollecting, also, that previous to the time of Reis, musical sounds had been reproduced with the apparatus which he uses as a receiver, it does not seem to me that the community is indebted to him for the initial step used in the majority of telephone transmitters now in use. Both his transmitter and receiver are absolutely abandoned, and a mode of operation of which he had not the slightest conception is the only one which is or ever can be utilized for the transmission of speech. All that Reis really did, it seems to me, was to substitute a circuit-breaker operated by the voice for a circuit-breaker operated in other ways. He evidently hoped to do very much more, but the more extended his experiments, so far as is shown by anything that has been published, the less sanguine did his hopes or the beliefs of others become.

The method by which he expected to transmit the voice being an impossible one, his idea of using that method is valueless in the transmission of speech. Finally, in reference to the last few clauses of your question, Reis never transformed the energy of sound waves into electrical energy. He simply caused the circuit to be periodically broken, because of the energy of sound waves. In such a case as this, the energy of the sound waves is no more transformed into electrical energy, than is the energy of the finger which pulls the trigger of a gun transformed into the energy due to the exploding powder; or the energy of the arm which opens a floodgate transformed into the energy of the stream which is let loose, or the energy of the hand that plants a seed transformed into the energy stored up in the tree that grows from it.

[*Adjourned.*]

BOSTON, June 8, 1883.

Cross-Int. 45. Please look at the instrument now shown you [*now put in evidence, and marked "Defendants' Exhibit Reis Transmitter, First Form, W. A. C., Special Examiner"*], and state how it differs, if at all, from that form first described by Reis and others.

[*The exhibit and the name given to it objected to, on the ground that it is totally different from anything described by Reis or others in the publications put in evidence, and is the direct opposite of the apparatus described by Reis in his lecture of October, 1861, in those particulars in which the production of an undulatory current as distinguished from an intermittent current depends.*

(N. J. MCDONOUGH)

[*In view of the objection of the complainant's counsel, the defendants' counsel adds to the questions the following:*] I refer you particularly to the report of Reis's lecture of 1861, and the cut therein contained.

Ans. Setting aside minor differences, I find this very important one. Speaking of the operation of his instrument, Reis says: —

"If now tones or tone combinations are produced in the neighborhood of the block, so that sufficiently powerful waves reach the opening *a*, then these sounds cause the membrane *b* to vibrate.

"At the first condensation the hammer-like wire *d* is pushed back; at the rarefaction it cannot follow the retreating membrane, and the current traversing the strip remains broken, until the membrane, forced by a new condensation, again presses the strip (proceeding from *p*) against *d*. In this way each sound wave causes a breaking and closing of the current." (See the Lecture, pp. 541, 542, *infra*.)

It appears from this statement that the construction of the hammer-like wire *d* is such that when the membrane moves away from it under the influence of a rarefied sound wave the wire *cannot* follow the membrane, so that the current is broken until the next condensation presses the strip that is attached to the membrane against this hammer-like wire. In the exhibit apparatus now produced and referred to in your question, the arrangement of the electrodes is totally different.

The hammer-like wire is attached to the end of a brass spring which presses this wire against the second electrode, bearing upon it in such a way that it tends to follow and can follow the retreating membrane to a very considerable extent, thus preventing the circuit from being broken if the person speaking into the instrument uses a low or moderate tone of voice, thus bringing about simple variations in pressure at the contact point of the two electrodes without necessarily producing a rupture of contact.

Cross-Int. 46. You don't consider, then, that the thin strip of metal which carries the electrode *d* in Reis's cut is a metal spring?

Ans. My understanding of the apparatus is, that the thin strip of metal which extends from the binding screw *n* to a point over the middle of the membrane, there terminating in the platinum wire *d*, is not a flexible strip pressing the wire *d* into contact with the other electrode so that the wire *d* can follow this electrode in its retreating motion, but a stiffer strip or a strip so set that it does not tend to follow the membrane as it recedes.

Cross-Int. 47. But you do believe that the strip from the binding post *p* is a light metal spring, do you not?

Ans. The strip connected with *p* must be of such a nature as to allow the membrane to vibrate, and therefore is, I suppose, thin.

Cross-Int. 48. I suppose you meant to answer my last question in the affirmative by implication from the word "thin." Does not the same implication clearly apply to the thin strip from the binding screw *n*?

Ans. I do not know that the metal strip referred to in the forty-sixth question is necessarily a spring. All that the lecture says regarding the metal is, that there is a conducting strip of platinum cemented to the middle of the membrane and which is in connection with the binding screw *p*. Regarding the wire which is attached to the binding screw *n*, all that is said is, that there is likewise a thin strip of metal which extends as far as the middle of the membrane, ending there in a platinum wire.

Cross-Int. 49. Don't you think it very likely that the strip from the post *n* is substantially the same as the corresponding strip in the Exhibit Reis Transmitter, first form?

[*Complainants object to substituting anybody's guesses for the written description published by Reis himself.*]

Ans. I have nothing beyond Reis's statements by which I can form any opinion upon this matter. I am very certain that if any one were constructing apparatus to act in the manner in which Reis states as a matter of fact that his apparatus did act, he would not make the apparatus with a metal spring as shown in your Exhibit Reis Transmitter, First Form, but would arrange the platinum wire so that it could not follow the retreating membrane, and the most natural mode of doing this would be to use a heavier or much stiffer strip of metal.

Cross-Int. 50. You mean, do you not, that he would make the piece of metal from binding post *n*, as Dr. Van der Weyde described it in his article, namely, not a "*thin strip* of metal," but a plate or bar substantially rigid, holding the electrode *d* away from contact with the electrode carried by the tympan when the tympan is not in vibration?

[*Complainants object that the question misstates the description by Dr. Van der Weyde.*]

Ans. He would certainly not use a piece of metal too thin to perform the function which Reis explicitly states was performed by the thin strips of metal referred to. It does not follow from this, it seems to me, that he would use a plate or bar. All that he would have to do would be to use a strip of metal which for convenience sake he would probably make thin rather than thick, and which he would not mount in such a way as absolutely to defeat the object which, in his copy of the Reis apparatus, he intended to secure.

Cross-Int. 51. Considering now the later form of Reis transmitter (Exhibit Reis Transmitter), have you any doubt that the tympan of transmitters of that kind were, as a matter of fact, actuated by the energy of sound waves from vocal and other sounds, so as to produce in the circuit what it is now become common to call the "undulatory current," by which I mean variations in the strength of a voltaic current similar in form to the vibrations of the air accompanying the vocal and other sounds acting upon the tympan of the transmitter, and that such variations of current strength were always produced

in every such transmitter ever coupled up in an electric circuit, and will be in all others that ever shall be so coupled up?

Ans. Your question is so broad in its references to the Reis apparatus that I find it somewhat difficult to answer it. It is certainly highly probable that accidentally and without their being recognizable, undulatory currents have been produced. I have seen no evidence to show that they were ever produced intentionally prior to the date of Mr. Bell's patent. As to whether any Reis transmitter ever has been or ever can be fitted up without the production of undulatory currents to a certain extent, all that I can say is, that when the apparatus was not in use for transmitting sounds, such currents would very possibly be formed by the vibration of the membrane by extraneous noises, and even when the pitch of sounds was transmitted by the apparatus during the brief periods of contact of the electrodes, some such electrical undulations may have been produced. Of this, however, I am certain, that if produced at all, they were produced accidentally and unintentionally without any one's being aware of their existence, knowing how to produce them, or ever having conceived of the idea of producing and utilizing them; so that they were, at most, mere waste products.

[*Adjourned.*]

BOSTON, June 9, 1883,

Cross-Int. 52. You are aware, I suppose, that Exhibit Reis Transmitter, when its diaphragm is submitted to a large class of vocal and other sounds, will cause electrical undulations in the battery current similar in form to the air vibrations accompanying sounds of that class; and when subjected to another class of sounds will cause a peculiar intermittent current which is very similar to the air vibrations accompanying such sounds to a certain extent, but not sufficiently so for practical use in the transmission of speech, because of the fact that the current is not only interrupted, but at brief intervals actually ceases; the two classes of sound I have in mind are (those last referred to) all vocal and other sounds of an intensity sufficient to break the contact between the electrodes of the Reis transmitter and (those first referred to) all vocal and other sounds of an intensity insufficient to do that.

Ans. If the Exhibit Reis Transmitter is so operated that the method of Mr. Bell and not that of Reis is used, that is, if the electrodes instead of parting contact with each other as the diphragm vibrates to and fro, remain in contact and so rest upon each other with a variable pressure, then electrical undulations will be produced. If, on the other hand, the method of Reis is used, such undulations will not be produced. The clause in your question which refers to the interruption and cessation of the current is utterly unintelligible to me, since the term "interruption of a current" has in electricity one meaning and one meaning only, that is, the breaking of the current.

Cross-Int. 53. I will repeat my question in a different form of words. You are aware, are you not, that the Reis transmitter is, under certain conditions as to intensity or loudness of sound, adapted for use under what you call the Bell method?

Ans. It is possible, with the Reis transmitter, to produce electrical undulations similar in form to the sound waves producing them.

Cross-Int. 54. And by electrical undulations, etc., in your answer, you mean precisely "electrical undulations similar in form to the vibrations of the air accompanying the" sound waves acting upon the tympan of the transmitter, do you not?

Ans. I do.

Cross-Int. 55. You are also aware, are you not, that the Reis receiver of the knitting-needle pattern will give out audible speech when actuated by currents of proper strength and form?

Ans. It is possible, as the defendants' experts have shown in this case, by using a very powerful modern microphone transmitter, to produce electrical undulations so powerful that with the knitting-needle receiver they will produce audible speech.

Cross-Int. 56, I don't think your answer is as responsive as it should be. Please answer the question again.

Ans. I do not understand in what respect my answer fails to respond to the question asked. If by "currents of proper strength and form" is meant currents which will cause the knitting-needle receiver to produce audible speech, my answer will of course be in the affirmative.

. . . . . .

Int. 133. State whether you do or do not find in any of the publications which have been put in evidence any indication that the various writers, or the persons whose ideas they profess to report, sought to produce, or conceived that it was desirable to produce, by any means or in any part of their respective instruments, electrical undulations similar in form to the sound waves constituting the sound sought to be transmitted, or even electrical undulations of any form as distinguished from electrical intermittences.

Ans. I do not find in any of the publications referred to any indication whatever that it was supposed by any one that it was desirable to produce electrical undulations rather than electrical intermittences, still less that it was desirable to produce electrical undulations similar in form to the sound waves constituting the sound to be transmitted.

Int. 134. What kind of variations do those publications show that the writers and experimenters directed their care to the production of and believed they had produced?

Ans. Intermittences.

Int. 135. In the attempts which you have made to transmit speech by the Reis apparatus, what care did you take to secure favor-

able conditions, and what success did you have? State how much you ever transmitted with it.

Ans. I have several times tried to transmit speech by means of the Reis apparatus. In the last and most successful experiments which I made, I took every precaution that I could think of to secure success. The transmitter and receiver were in separate rooms in the same building, the receiver was in a room which was absolutely quiet, the receiving and transmitting rooms were connected together by a telltale line furnished with speaking telephones. The time chosen was a holiday and the building was closed. No one was in the rooms except those taking part in the experiments, and absolute quiet was secured.

Anything which I thought that I heard with the Reis apparatus was transmitted by the telltale line to the transmitting room, and the words which were actually spoken into the Reis transmitter were transmitted to me through the telltale line. The speaker at the transmitting end was a person accustomed to the use of all kinds of telephonic apparatus, with whose voice I was perfectly familiar. He was requested to speak with as great loudness as was consistent with a preservation of the unbroken contact between the electrodes of the transmitter, and from time to time he was communicated with through the telltale line, that he might speak louder, or less loud, as the experiment seemed to require. I listened very carefully at the receiving instrument, and several times thought that I understood short sentences which were transmitted, but found on inquiry through the telltale line that I was mistaken. The only sentence which I heard correctly was one which had invariably been used by the same speaker in testing different kinds of telephones with me, and which I could recognize even by its rhythm. The sentence was, "The sun is shining brightly," which was actually the case at the time.

I was, at the time that it came, conscious that its rhythm as much as anything else enabled me to recognize it. I also recognized the clause, "It is half-past ——" The sentence spoken into the transmitter being, "It is half-past five."

This was also a sentence which it was customary for the speaker to use with me as a listener in testing telephones, and here again the rhythm was a sufficient indication of the sentence to enable me to recognize all except the last word. This was all I succeeded in recognizing, although the experiment lasted about an hour. In my experience in testing telephones,—the efficiency of telephone transmitters and receivers,— I have not felt at liberty to rely on the recognition of familiar and frequently repeated sentences, since it is easy to recognize such sentences from rhythm alone, although there is no proper articulation.

Int. 136. Will you state how nearly the Reis apparatus used by you on this occasion resembled defendants' Exhibits Reis Transmitter

and Reis Receiver No. 1, particularly as regards size of diaphragm, and material and weight of hopping piece of the transmitter?

Ans. The Reis apparatus used by me was as perfect a reproduction as possible of the defendants' Exhibits Reis Transmitter and Reis Receiver No. 1. The only differences that I could find were that the reproduced receiver did not have some of the cracks which were present in the Exhibit Receiver, and that the wood of which the apparatus was made was of a different material.

. . . . . .

Int. 138. In several of the Reis publications the peculiar tone or sound produced at the Reis receiver is noticed. Thus Pisko states (record, page 586) : —

"Its strength not very remarkable, and its clang [quality] buzzing, like that of a weak-sounding reed-pipe, something like a child's trumpet."

Kuhn, record, page 598, says : —

"The quality of the sounds thus produced is not pleasant. They are almost like the sounds of toy trumpets at times, also like the buzz of a fly caught in a spider's web, and the like."

Dr. Van de Weyde, page 609, says : —

"The receiving instrument in fact sings the melodies transmitted, as it were, with its own voice, resembling the humming of an insect, regardless of the quality of the tone which produces the original tune at the other end of the wire."

Will you state whether in using the Reis apparatus you have observed this characteristic buzzing sound at the receiver, and whether it is due to a circuit-breaking action or to a michrophonic action of the transmitter?

Ans. I have frequently noticed the buzzing sound, which is very marked and peculiar, resembling almost exactly the buzzing of a fly, and it is produced only when the transmitter is so operated as to make and break the circuit.

The quality of sounds transmitted microphonically is quite different. I have tried the experiment of having the person at the Reis transmitter sing a single prolonged note into it, at first very gently, so as not to break the circuit, then more loudly, so that the circuit was broken at each vibration of the membrane. I could always tell the moment at which microphonic transmission of the sound ceased, and transmission of the pitch alone by the action of the transmitter as a circuit-breaker began, by the sudden change of the quality of the sound heard at the receiver, this peculiar buzzing quality appearing immediately upon the beginning of the breaking of the circuit by the transmitter.

Int. 139. In that experiment could you tell by the relative loudness of the sounds when the microphonic action ceased and the circuit-breaking began, and how marked was the difference?

Ans. The loudness of the sound is far greater when the circuit is broken than when the sound is transmitted microphonically. In the latter case I could only hear the sound by placing my ear closely against the receiving instrument, whereas, in the former case, the sounds produced by the receiver were loud enough to be distinctly audible throughout a very large room.

Int. 140. In your fifty-first cross-answer, page 508, you have stated that while the circuit is being made and broken at each vibration of the membrane, some slight electrical undulations might possibly be produced during the brief instant when the electrodes were in contact between two successive interruptions. Will you state whether such fragmentary interruptions which can thus be produced would give an effective undulatory character to the current, as a whole, or whether they would be overshadowed and their possible theoretical effects overpowered by intervening interruptions?

Ans. The interruptions are so frequent and the sound due to them so loud that the minute effects referred to in my fifty-first answer would be entirely overpowered, and it would be practically impossible for them to give any undulatory character to the current as a whole. Whatever minute undulations might be produced would be entirely devoid of practical value, even if they could be observed at all.

Int. 141, Were circuit-breakers (by which I mean devices which absolutely broke off the current and then let it flow again while alternately opening and closing the circuit) known to and in use by electricians in 1860; and if so, will you state whether the phrase used in the German publications relating to Reis, to characterize his apparatus and the operations which he performed, was the same as that technically applied to other circuit-breakers?

Ans. Circuit-breakers were constantly employed by electricians at the date mentioned. The phrase by which the apparatus and operation of the Reis transmitter are designated are the same as those technically applied to other forms of circuit-breaker; thus, in the Reis lecture as published by Reis, on page 542, I find among others the following expressions, of which I give both the English and the German: "In this way each sound-wave causes a breaking and closing [ein Oeffnen und ein Schliessen] of the current [Stromes]. . . . On breaking the circuit [beim emterbrechen des Stromes] these atoms seek to regain their position of equilibrium. . . . This is the case if the making and breaking of the current [Unterbrechungen und Schliessungen des Stromes] occur with comparative slowness." . . .

"The iron wire no longer gives its longitudinal (normal) tone, but a tone whose pitch corresponds to the number of interruptions [Unterbrechungen] (in a given time): this is the same as saying that *the rod reproduces the tone* [*ton*] *impressed upon the interrupter* [*dem Unterbrechungs apparat*]."

In Kuhn's description of Reis, page 393 of the record, the term "Unterbrecher" is applied to a well-known form of circuit-breaker;

"Yet the possibility cannot be controverted that the principle of Neef's circuit-breaker [Unterbrecher] might contribute to the solution of the problem in question."

On page 594 the same term is repeated.

In Müller-Pouillet's description of Reis, page 603 of the record, I find an ordinary circuit-breaker is denominated by the same term (Unterbrechungs apparat) that is applied a few lines below to the Reis transmitter.

The term "unterbrechung" is the ordinary term technically used to indicate the breaking of the circuit, and the term "unterbrecher" or "unterbrechungs apparat" is a technical designation of a circuit-breaker. It never has any other meaning than this.

Int. 142. Is the book of Kuhn, which you have just referred to, a standard work of recognized authority or not?

Ans. It is a standard work, and was the best work in German upon the subjects of which it treats at the date of its publication, in 1866."

[*Counsel for complainants puts in evidence an official translation from the bound volumes of the Patent Office, of the specification of the German Patent No.* 4,000, *granted to Robert Lüdtge, Jan.* 12, 1878, *for Improvement in Transmitter and Relay for Electric Telephones.*

Objected to as incompetent and immaterial. If complainants wish to avail of the testimony of Robert Lüdtge in regard to the matters of which his alleged patent treats, he should be called as a witness in the regular way.]

Int. 447. Have you examined the German Patent to Robert Lüdtge, dated January 12, 1878, and just put in evidence, and do you understand the construction and mode of operation of the apparatus therein described? If so, please state upon what principle such apparatus operates.

[*Objected to as immaterial.*]

Ans. I have examined the patent referred to, and understand the construction and mode of operation of the apparatus therein described. It is a microphone transmitter, and produces electrical undulations by varying the intimacy of contact between two electrodes.

Int. 448. You have been asked about a contrivance or arrangement of tuning-fork circuit-breakers, tin box, and electromagnet, which you and Prof. Pickering had used; and about deposition which you gave in 1879, a copy of which, have h

produced and put in evidence. Will you please state what invention or alleged invention the facts stated in that deposition were intended to meet or anticipate?

Ans. I understood at the time that the experiments were called for in my deposition, because the apparatus antedated an apparatus which Mr. Elisha Gray had patented, in which there was a metallic plate opposite the poles of an electro-magnet, which plate was set into vibration by the action of a circuit-breaking tuning-fork, a form of harmonic telegraph by which musical sounds were produced at the receiver by these interruptions of the circuit.

I understood that Mr. Gray found, subsequently to Mr. Bell's invention of the speaking telephone, that his receiving apparatus could be used as a speaking telephone receiver by using the method of producing and employing electrical undulations invented by Mr. Bell. I found on experiment that the apparatus which I had described in my 1872 lecture, which was previous to the experiments of Mr. Gray, was also capable, when used as a receiver in connection with a transmitter employing the method devised by Mr. Bell, of acting as a speaking telephone receiver.

Int. 449. Will you please designate the different receiving instruments of Mr. Gray, which you referred to in your last answer, by the names by which they have commonly been known in telephone litigation since the Bell patent?

Ans. I mean those instruments which have been called the "wash basin," the "tin-dipper," and the "blacking-box" receivers respectively. I understood that some of these instruments had been patented, but not which particular ones.

Int. 450. Referring now to the contrivance which you or Prof. Pickering rigged up, consisting of a sonometer circuit-breaker or tuning-fork circuit breaker at one end of your laboratory line, connected with an electro-magnet and tin box at the other, will you please state whether that apparatus as a whole was or was not used for the transmission of speech, or intended for the transmission of speech?

Ans. The apparatus was neither used nor intended to be used for the transmission of speech.

Int. 451. State whether it was by construction adapted for the transmission of speech.

Ans. It was not at all adapted for the transmission of speech, and as a whole was quite a different apparatus from what any one familiar with physics would have devised for transmitting speech.

Int. 452. Will you state whether the sounds which you intended to produce and did produce by it were caused by interruptions of current, or by electrical undulations similar in form to sonorous air vibrations produced at the transmitting station?

Ans. They were produced entirely by interruptions of the current.

Int. 453. Will you state whether the apparatus was actuated, or intended to be actuated, by sound waves produced at the transmitting station?

Ans. It was not.

Int. 454. Please state briefly what knowledge you had in 1872 about the Reis apparatus and its mode of operation, and what attention you had given to its merits or demerits.

Ans. I have looked over all of the books bearing upon the subject which I had in my possession or would have referred to previous to my 1872 lecture, and in which any description of the Reis telephone is to be found, The only description which I can have read previous to that time is the notice of the instrument given in Koenig's Catalogue of Acoustic Apparatus, and which is found translated on page 581 of the Dolbear record. This was all that I knew about the apparatus, and if I had heard anything from other sources, I learned nothing beyond what is given in this statement. I understood that it was not a success for the transmission of speech, and that it was very imperfect for the transmission of any sounds. I had not studied its operation minutely, nor had I reached any opinion as to why it was so inefficient. We had in our collection of apparatus the Wertheim coil and core, which is substantially the Reis receiver. I should say that to the best of my recollection, I thought of the Reis receiver as being electrically imperfect, rather than the transmitter, but did not consider the subject very seriously.

Int. 455. Referring to your last answer, will you state how seriously you had then considered the subject of the Reis transmitter, and what could or could not be done by the mode of operation attributed to it?

Ans. So far as I can ascertain, my whole knowledge of the Reis apparatus did not exceed what is given in Koenig's catalogue. I have carefully looked over my manuscript notes, which are exceedingly full, of all the lectures on acoustics which I had then heard, and I cannot find in them any reference to the Reis apparatus. I knew that the apparatus was on the whole a failure, and was, of course, familiar with Koenig's statement as to the difficulties which were found in the operation of the transmitter, having had a copy of his catalogue in my possession for several years. I saw an acoustic difficulty in the Reis transmitter, as I thought that the membrane would not take up all of the sounds which were produced in the air. Having recognized this difficulty, I did not consider further the matter of the perfection or imperfection of the Reis transmitter.

The statement given in Koenig's catalogue to which I refer is as follows:

From KOENIG'S "Catalogue des Appareils d' Acoustique," Paris, 1865, page 5.

"29. TELEPHONE OF M. REIS. 60 Fr.

"This apparatus is intended to transmit sounds to a distance by means of electricity. It rests upon the fact demonstrated by the preceding apparatus. [*The preceding apparatus was the Wertheim coil and core, which Reis uses for a receiver.*]

"At the first station the current traverses a little band of platinum, which is attached to a membrane in such a way as to follow all its movements, and of a very movable point which rests lightly upon this membrane. At the other station the current traverses a coil, at the centre of which is a bar of soft iron. If now, we produce before the membrane a sound which causes it to vibrate, each vibration in pushing away the point from the platinum plate will produce an interruption of the current. On the other hand, each meeting of the current will produce in the bar of soft iron at the second station, a momentary and weak sound. It is the rapid and isochronous succession of these sounds, all acting as simple blows, which produces the continuous sounds that are heard. It is true that they are not of good quality, and that they cease from time to time. This comes from the fact that the membrane does not vibrate equally well for all tones, and because the manner in which the vibrations determine the interruption of the current by pushing the little point away from the plate, is far from being perfect."

Int. 456. What views did you then entertain about the tin packing box which you used as a receiver, as compared with the Reis knitting-needle receiver, or such modification of it as you had at the Institute in what you call the Wertheim core and coil?

Ans. From the large surface of the plate and its known capacity of vibrating in many different ways, I inferred that the apparatus ought to make a better receiver than that of Reis. It seemed to me to be much better adapted to reproduce vibrations in general than was the Reis knitting-needle receiver.

Int. 457. You were asked on cross examination about a statement which you made in a lecture about February, 1872. Will you please tell us what that statement was, and what led you to make it?

Ans. The lecture was delivered at the time that preparations were in progress for the Peace Jubilee, as it was called, which was held in the summer of that year, and some of those present were interested in that exhibition. After exhibiting the tin-box apparatus, I remarked that by a modification of the transmitter it would be possible to transmit the music of the jubilee to different portions of the country, so that the audience need not come to the concert room. I also suggested that the singers might remain at their homes and their music be transmitted, and that it might be possible to transmit speech over the country.

Int. 458. Did you suggest or know of any means, method or apparatus by which that could be done, and if so, what?

Ans. I did not. The only transmitting apparatus which I had in mind was the Reis transmitter, if the difficulties which I understood were met with in operating it could be removed. My only definite thought was with regard to the receiving apparatus.

Int. 459. Did you have any ideas as to how those difficulties could be removed, or did your mind consider that subject?

Ans. I did not have any definite ideas. According to the best of my recollection, the difficulty seemed to me, as far as I had considered it, to be the acoustic one that I have mentioned. Beyond this, I did not consider the subject.

Int. 460. When and from whom did you first hear of the idea of creating and employing electrical undulations corresponding to sound waves as a means for transmitting speech by electricity?

Ans. From Mr. Bell. It was in the autumn of 1874, according to the best of my recollection.

Int. 461. Did he at or about that time, and during that fall or winter of 1874–5, state to you anything concerning the structure of the instrument which he proposed to employ in the transmission of speech, upon this plan?

Ans. I understood that he wished to produce electrical waves which should be like sound waves in their form as well as in their number. These were to be produced in some way by vibrating a piece of iron in front of the pole of a magnet.

Int. 462. Did he tell you how he proposed to vibrate this piece of iron, and by what kind of a contrivance?

Ans. As far as I can recollect, he proposed to set a membrane in vibration by the voice and have the membrane actuate the piece of iron.

Int. 463. Did you form any opinion at that time as to the theoretical perfection or imperfection of that plan for the transmission of speech?

Ans. I thought that the instrument was theoretically perfect, but did not suppose that it would produce vibrations which would be strong enough to produce any effect on a receiver.

Int. 464. When did you first try or see any one else try to transmit speech by electricity, and whose instrument was it that was tried?

Ans. In the spring of 1876, when Mr. Bell exhibited his telephonic apparatus at a meeting of the Society of Arts at the Institute of Technology. I first saw the apparatus on the afternoon preceding his lecture, which was given in the evening.

Int. 465. When you used that packing box, which you described on your cross-examination, with the circuit-breaking tuning-fork, how much battery power did you apply to produce its vibrations?

Ans. Six Grove cells.

Int. 466. When and how did you first come to believe that that packing box and magnet could produce audible and distinguishable articulate sounds under the influence of articulating electrical undulations, such as are produced by a good microphone?

Ans. In 1879, when I first tried it, as I have described in my

deposition in the Harmonic Telegraph case. I had previously doubted whether the electro-magnet and box which I used were capable of reproducing speech with such currents as are given by a magneto telephone or a Blake transmitter, on account of the large size of the magnet and box; and I remember remarking, soon after the invention of Prof. Bell's magneto-receiver with an iron plate, that Prof. Pickering and I had been going in the wrong way in increasing the size of our apparatus.

Int. 467. Will a large magnet and plate produce stronger and better or weaker and worse articulation under the influence of such currents than a small magnet and plate?

Ans. The articulation will be weaker and less distinct.

Int. 468. If you take exactly the apparatus and arrangement which you had when you used that box, as stated in your cross-examination, can you or can you not, by the application of Mr. Bell's method or any other that you know of, and with the aid of all your present knowledge and experience, transmit articulate speech by talking to the transmitter and listening at the receiver?

Ans In June, 1885, I set up the original apparatus, using the same box, electro-magnet and forks that I used in my experiments of 1872 and 1873. I used six cells of Fuller battery, which is, electrically, substantially equivalent to the six Grove cells of my early experiments.

With those forks which I used in 1872, I used, as then, styles of brass forming one electrode, and dipping into a cup of mercury to complete the circuit. With another fork which I used in 1873, I employed a platinum style. I placed the magnet, in my experiments with each fork, opposite the bottom and also opposite the end of the box. I placed the magnet, in the experiments with each fork, at the distance from the box at which it gave the best results as to loudness of sound, when the fork was employed as a circuit-breaker; and I also placed the electro-magnet as close as it could be placed to the plate, without having the plate drawn into contact with the poles of the magnet through their attraction upon it. I tried very carefully with all of these adjustments to transmit speech by having a second person speak and shout loudly to the tuning-fork transmitter, while I listened attentively in a quiet room, and with my ear

close to the receiving instrument to hear any sound which might be transmitted. I did not hear any speech or sound of the voice whatever with any of the forks. Most of the forks of the transmitter I adjusted myself, as I have always been in the habit of adjusting such circuit-breaking forks, with the brass or platinum electrode carried by the fork dipping by a very slight amount beneath the surface of the mercury when the fork was not in vibration.

Int. 469. In the experiment just referred to, did you or did you not aid yourself by a telephone telltale line between the two stations, and cause the whole operation to be conducted in the way best calculated to obtain speech from such an apparatus, according to your present knowledge and experience?

Ans. I did make use of a telltale line as an aid in adjusting and operating the apparatus. I also did my best with my present knowledge to obtain a transmission of speech by means of the apparatus.

[*Counsel for complainants puts in evidence the diploma from the Heidelberg University of Germany, to Alexander Graham Bell, conferring upon him the honorary degree of Doctor of Medicine; and also a translation of the same.*

Objected to as immaterial and incompetent, particularly in view of the fact that no evidence is offered as to the conditions under which the said diploma was secured, or as to the accuracy of the alleged translation of the same.

Counsel for complainants also puts in evidence a certified copy of an affidavit made by the late George Gifford, Esq., filed in the case of American Bell Telephone Company v. John J. Ghegan in the Circuit Court of the United States for the District of New Jersey.

Objected to, as incompetent and inadmissible.]

TRANSLATION OF MR. BELL'S HEIDELBERG DIPLOMA.

May this event be fortunate. Under favor of the most august and powerful prince and lordly ruler, Frederick, Grand Duke of Baden, Duke of Zahringen, etc., the academy's most stately rector, the stately vice-rector of the academy being that most renowned and illustrious man Immanuel Bekker, doctor of both laws, public professor in ordinary of Roman law to the Grand Duke of Baden, mem-

ber of the privy council, knight of the Order of the Lion of Zahringen — we, the dean, senior, and other professors of the Order of Physicians in the Ruperto-Carolina University of Letters, at the time of our celebrating the five hundredth anniversary of the founding of our university, have duly conferred the honorary title of Doctor of Medicine, (and by this diploma authenticated by the seal of our order have borne witness thereto), upon that distinguished man Alexander Gr. Bell, a Scotchman, who as he conferred on mankind the great and constantly increasing benefits of labor saved by his ingenious discovery of the telephone, likewise by his most accurately devised chronograph, not only aided physics in no ordinary degree, but also physiology, and furnished the medical profession a means of deciding important matters.

Done at Heidelberg, in the Ruperto-Carolina literary University, August 5, 1886.

DR. GUIL. DELFFS H. T. SENIOR.	DR. THEOD. DE DUSCH H. T. DECANUS.
DR. CAROLUS GEGENBAUR.	DR. VINCENTIUS GERNY.
DR. GUIL. KUEHNE. [SEAL]	DR. FERD. ADOLF. KEHRER.
DR. OTTO BECKER.	DR. CAROL FÜRSTNER.
DR. JULIUS ARNOLD.	DR. GUIL. ERB.

Adjourned.

DECEMBER 18, 1886.

[*In view of the seventh objection of defendants' counsel to the introduction in evidence of the notes of experiments in the Dolbear case, which relate to the Reis apparatus proper, on the ground that they constituted only a part of the record of the full experiments, counsel for complainants now puts in evidence all the rest of the notes so referred to in the objection, to be annexed to this deposition, and entitled "Notes of Experiments in the Dolbear case, relating to the use of Reis transmitter with modern magneto receivers, and of Reis receivers with modern carbon microphone transmitter."*

Defendants' counsel objects to the introduction of the foregoing matter, for the six reasons first given by way of objection to the introduction of the previous matter from the Dolbear case.

Int. 470. In the notes just put in evidence, and in your answer to Int. 33, which you have read from your deposition in the Dolbear case, reference is made to Magneto Receiver No. 9 and Magneto Receiver No. 10, which were used with the Reis transmitter. What kind of magneto receivers were these?

Ans. They were modern magneto receivers, furnished with a permanent magnet, a metallic diaphragm, and with a coil wound round that end of the magnet which is opposite the diaphragm.

Int. 471. Will you compare the Reis transmitter, described in the Reis publications, with any common modern microphone transmitter, and point out how the physical and mechanical features of each adapt it to perform its characteristic operations when operated under the ordinary force of the voice?

Ans. In the Reis transmitter the anvil electrode is of small mass and light, so as to be especially adapted for effecting a break in the circuit, while in modern microphone transmitters, as the Blake transmitter, the anvil electrode is of large mass and heavy, so as to be especially adapted for effecting variations in resistance without producing a break in the circuit. In the Reis transmitter the material of both electrodes is platinum, a substance which is especially adapted for use in a circuit-breaker, but which is not at all adapted for use in a microphone; while in modern microphone transmitters one or both of the electrodes are of carbon, a substance which is admirably adapted for use as a microphone, but which is very poorly adapted for use in a circuit-breaker.

Int. 472. You have in the course of your present deposition stated the results of experiments made by you as to the effect of breaks in a telephone circuit containing a battery. What, in your judgment derived from your experiment and observation, as well as from your knowledge of the sciences of electricity and acoustics, are the possibilities of the transmission of speech by any telephone apparatus having a battery in circuit, when the transmitter is so operated as to make and break the electric current as often as once at each full or complete vibration of the diaphragm? I intend this question to be broad enough to cover the arrangement of the receiver, either in the secondary circuit of an induction coil or in the primary circuit containing the transmitter and battery.

Ans. In my judgment it would be absolutely impossible to transmit speech by any apparatus operated as suggested in your question.

Cross Examination Resumed.

Cross-Int. 473. Would that result depend upon the fact that the battery current is interrupted as frequently as is assumed in the question, or upon the fact that the interruptions are effected by breaks in the circuit *at the particular point where the electrodes are situated?*

Ans. In my opinion this result would follow whether the breaks occurred at the electrodes or at some other point in the circuit; although in the former case certain additional disturbing elements would exist which are absent in the latter case.

Cross-Int. 474. And in your judgment also it would make absolutely no difference whether the breaks occurred in the primary circuit of an induction coil, the receiver being in the secondary of such coil; or in a direct battery circuit connecting the transmitter and receiver?

Ans. Other things remaining the same, I do not see why this should make any sensible difference; assuming, of course, that the induction coil is one of the ordinary construction such as is used for telephonic purposes.

Cross-Int. 475. Did you in your answer to Int. 471 name all the differences between a Reis transmitter and a common microphone transmitter, which you deemed to be material?

Ans. I named those especially which I thought to be evident beyond all dispute, and of prime importance. I cannot say that no other differences are material, though they are inconsiderable as compared with the two specified.

Cross-Int. 476. I find Cross-Int. 43 and the answer thereto of your desposition in the Dolbear case to be as follows: —

"*Cross-Int.* 43. In the great majority of all telephones now in use there is a very short battery circuit with an instrument in it, sometimes called a microphone transmitter, and sometimes called a Blake transmitter, and sometimes called a battery transmitter. What, in your opinion, are the substantial differences between such a transmitter and Exhibit Reis Transmitter? Please name all that you believe to be substantial.

Ans. The Blake transmitter has a metallic diaphragm; the Reis instrument has a membrane diaphragm. The Blake transmitter has a narrow space in front of the diaphragm, between it and the mouthpiece; the Reis transmitter has a long speaking tube, and a cubical box between it and the membrane. The Blake transmitter has a heavy anvil electrode; the Reis apparatus a very light anvil electrode. The Blake is also furnished with an induction coil, though this is not essential; the Reis has no such induction coil.

In the Blake the rear face of the diaphragm and the electrodes are protected from disturbance due to extraneous vibrations by being completely closed within a box; in the Exhibit Reis transmitter,

these electrodes are open to the air, although from the appearance of the instrument there may have been a glass cover placed over the electrodes.

The Blake transmitter is arranged so that the voice of the speaker acts directly upon the membrane without the intervention of any long speaking tube; in the Reis instrument the speaking tube is several inches long.

Did you so testify in that case, and do you still entertain the views there set forth?

Ans. I did so testify. I did not in that answer mention the difference in the material of the electrodes which I then thought, as I now think, to be very material. I must have omitted to mention it in my answer in the Dolbear case accidentally. With this addition, I still hold the views set forth in that answer.

Cross-Int. 477. Collating your said answer in the Dolbear case, with your answer to Int. 471 in the present case, I understand you to point out the following material differences between the Reis transmitter and what you call the common microphone transmitter: —

1. That the former has a membrane diaphragm, and the latter a metallic diaphragm.

2. That the former employs metal electrodes, and the latter at least one carbon electrode.

3. That the former has a very light anvil electrode, and the latter a heavy one.

4. That the former has no induction coil, and the latter, in some forms, has such coil.

5. That the former in the cubical box form has a long speaking tube and a cubical box between the tube and the membrane, while the latter has a narrow space in front of the diaphragm between it and the short mouthpiece.

6. That in the latter the rear face of the diaphragm and the electrodes are protected from disturbance due to extraneous vibrations by being completely enclosed in a box; while in the former, in some forms at least, the electrodes are open to the air. Do you find that any one of these material differences between the Reis transmitter and the ordinary commercial telephone is pointed out in Mr. Bell's patent of 1876?

Ans. I find no specific reference to any one of them.

Cross- Int. 478. In answering the last question you added, after the sentence which stands as your answer thereto, the following words, to wit, "I wish to observe, however, that these differences in themselves are mechanical in their nature." These words were taken down by the examiner, and then, at your request, erased. Please explain why you thought it necessary to add that sentence to your first statement, and why you erased it.

Ans. My reason for adding the sentence was that I could see no reason for expecting matters of this kind to be mentioned in the first Bell patent which deals with a method and the general construction of apparatus for carrying out that method, rather than with specific details. I also thought of calling attention to the fact that *Int.* 471 especially called my attention to physical and mechanical differences which tended to produce a certain effect. I did not wish to make a long statement which was not a portion of a direct reply to the question. I therefore tried to express the underlying idea which I had, in a short sentence. When I had framed this sentence, I saw that although true as stated, it was nevertheless susceptible of gross misinterpretation, and I therefore asked to have it removed from my answer.

[*Recess.*]

Cross-Int. 479. What is the lightest electrode that can be used in a microphone transmitter for transmitting speech?

Ans. This question is not susceptible of a catagorical answer.

Cross-Int 480. What is the lightest electrode that you have ever known to be used in a microphone when speech was being successfully transmitted?

Ans. I cannot say.

Cross-Int. 481. Give the best estimate that you can?

Ans. I have known speech to be reproduced by a Reis cubical box transmitter in connection with a magneto receiver, the transmitter being used as a microphone. The weight of the anvil electrode in this case was 16.2 grains. I once used as an anvil electrode a small piece of tin foil, which I think weighed less than this. In both cases particular care had to be taken to avoid the tendency to break the circuit due to the small mass of the electrode.

Cross-Int. 482. Do you not know of some form of microphone in

which if the anvil electrode be made of carbon, and the diaphragm be made of suitable thickness, a much less weight of electrode than 16.2 grains would suffice for the practical transmission of speech?

Ans. I do not recall any instrument constructed as you describe. I do not doubt, however, that with care I could succeed in transmitting speech experimentally with a considerably lighter electrode than the one whose weight I have stated, if of carbon.

Cross-Int. 483. Does Reis anywhere state how heavy the electrode of his cubical box instrument is to be?

Ans. He does not state explicitly. The weight which I mentioned is that of a transmitter which was made in Germany, and, if my recollection is correct, by Albert, who worked under Reis's direction.

[*All of the foregoing answer, after the word "explicitly" is objected to as not responsive to the question, and as immaterial.*]

Cross-Int. 484. From parts of your present deposition I understand you to hold that if the transmitter of a microphonic telephone be so actuated by sound waves as to cause electrical undulations substantially similar in form to such sound waves, the apparatus and its mode of operation will be within the scope of the fifth claim of Bell's first patent, even though the apparatus is not sufficiently sensitive or otherwise sufficiently perfect to transmit speech. Now, do you also hold that so long as the electrodes of a microphonic transmitter when subjected to the action of sound waves preserve contact, the current on the line will be put into undulations substantially similar in form to the sound waves acting on the transmitter?

Ans. I should suppose that this would be the case, though when the pressure is very slight such deviations from the law of ordinary microphonic action might occur as to prevent the electrical undulations from being similar in form to the sound waves. That is — they might be so distorted that we could not properly call them similar in form.

Cross-Int. 485. Did you intend this to be an affirmative or a negative answer?

Ans. Affirmative as a whole; though I wished to call attention to the existence of some special and peculiar cases.

Cross-Int. 486. Then, if I understand you, there are some cases

in which a microphone when so acted on by sound waves, as not to cause the electrodes to break contact, will, nevertheless, so shape the electric current on the line, that it will not consist of undulations similiar in form to the sound waves?

Ans. There are some cases, as when the pressure is exceedingly light, and the air waves so strong that the breaking point is approached, though not reached, in which very considerable distortion of the electrical undulations occurs. This may take place to such an extent that speech is not recognizable. This is the action which I intended to point out in my answer to *Cross-Int* 484.

Cross-Int. 486. I suppose you intended by your answer to Int. 434, to give it as your opinion that Reis intended his electrodes to break once for each full vibration of the diaphragm, corresponding to the fundamental of a given sound, and not to break for those modifications of the vibration produced by, or corresponding to the overtones?

Ans. I did.

Cross-Int. 487. Do you also hold that with each break of contact between the Reis electrodes, the receiving magnet was to be demagnetized?

Ans. This is the statement made by contemporary writers, whose publications have been put in evidence in this case. I suppose, therefore, that Reis designed that this magnetization and demagnetization should occur.

Cross-Int. 488. By this, do you understand that the demagnetization was to be complete?

Ans. Inasmuch as Reis, in some cases, speaks of using a steel needle for his receiver, which he must have known would retain a large amount of permanent magnetism, I suppose that what he and others describing his apparatus mean by "magnetization and demagnetization," is a sudden rise to a much more strongly magnetized state on the making of the circuit, and an equally abrupt falling off in the magnetization back to the original amount on the rupture of the circuit.

Cross-Int 489. But in all cases, as *you* understand it, the needle was to return to its original or normal magnetic condition with each break. Do you so hold? By "normal magnetic condition" I mean its condition when the circuit is permanently broken.

Ans. That I understand to be the action described by contemporary writers in treating of the Reis apparatus.

Cross-Int. 490. And not by Reis himself?

Ans. I do not find this distinctly stated in any article written by Reis himself. In his letter to Ladd he says that "the steel axis at Station B will be magnetic once for every full vibration."

Cross-Int 491. Now do you understand that the magnet of Reis's receiver would in fact return to its normal magnetic condition at each break of the circuit; assuming the breaks to occur once for each full vibration of the diaphragm under the action of sound waves generated by ordinary speech?

Ans I cannot say certainly, as this would be influenced by numerous circumstances, especially by the length of the break. If the break were as long as I have judged it to be in my answers to Cross-Ints. 304 and 305, I should think it would. If the breaks were very short I should think it very doubtful if it would entirely return to its normal condition. The material of the wire whether steel or iron, would also produce differences.

Cross-Int. 492. Have you ever experimented with a Reis-Legat receiver?

Ans. I think that I tried a few experiments with one a great while ago, but I have a very indistinct remembrance of them.

Cross-Int. 493. Have you ever transmitted speech with a microphone instrument when the electrodes were so adjusted as not to be in contact at all?

Ans. Not by microphonic action with such a transmitter. I have produced a powerful electric arc between such electrodes, using a strong current with a battery of from forty to sixty cells, and readily transmitted conversation in this manner. Whent hus used, the electrodes never came into contact.

Cross-Int. 494. Do you know where Professor Pickering lives at the present time?

Ans. I do; at the Harvard College observatory, Cambridge.

Cross-Int. 495. Have you read the diploma of Mr. Bell, which has been put in evidence during your examination?

Ans. I have not.

Cross-Int. 496. Have you read the translation of the same which has been put in evidence by the complainants?

Ans. I have not.

Cross-Int. 497. Please do so now, and state, if you know, what the invention or apparatus is which is referred to in that document under the name of "chronograph."

Ans. I suppose it must be Mr. Bell's form of the induction balance.

Cross-Int. 498. Do you regard the term "chronograph" as properly descriptive of the induction balance?

Ans. I do not, in English.

Cross-Int. 499. Was the principle of Bell's induction balance materially different from other induction balances of earlier date?

Ans. Not materially. It differed in details only.

Cross-Int. 500. Did not Bell's principal feat with his induction balance, consist in wrongly locating the ball in Garfield's body?

Ans He made the same mistake that the physicians did.

Cross-Int. 501. You have referred in your redirect testimony to certain conversations with Mr. Bell which you think may have taken place in the winter of 1874 and 5, and relating to the electrical transmission of speech,— did you make and have you preserved any memorandum of those conversations?

Ans I did not make any such memoranda.

Cross-Int. 502. If defendants should desire would you be willing, for proper compensation, to furnish a duplicate of the mechanism with which you performed your experiments in 1872, about which you have testified?

Ans. I should be perfectly willing to do so, or to lend them the originals, except at such times as I had occasion to use the tuning-fork.

Cross-Int. 503. In your testimony about Prof. Dolbear's experiments with the Reis instruments, you say "Prof. Dolbear heard 'Mary had a little lamb' three times, and 'Mary had a little' once. At the time when he thought he heard these words no such phrase was uttered into the transmitter." Did you intend that last statement to apply to the four utterances in front of the transmitter?

Ans. I did.

Cross-Int. 504. Do you not understand that Prof. Dolbear disputes the correctness of this statement of yours.

Ans. I did not know that such was the case. My recollection is, with regard to certain of these repetitions that we discovered the true state of the case at the time. I cannot say, however, after this interval of time that we then discovered this to be true of all four utterances, but this was what I made out from the reports and in connection with my own notes and recollections, to have been the case, immediately after the experiments, before I gave my deposition in reply

[*Adjourned.*]

DECEMBER 28, 1886.

Cross-Int. 505. Referring to Bell's Heidelberg diploma, what leads you to suppose that the invention therein referred to as a "chronograph" was "Mr. Bell's form of the induction balance," as asserted in your answer to Cross-Int. 497?

Ans. I knew of no other instrument of Mr. Bell's which it was especially intended to employ in physiological investigations; and realizing fully the difficulties which the faculty of the literary university had to contend with in finding in any dead language suitable terms to designate modern inventions, I assumed that they chose the best terms that they could find for their purpose. There is, of course, a time element which comes in, in the operations of the induction balance, and the term "chronograph" has frequently been used as synonymous with "chronoscope" in cases where there is no graphical record made.

Cross-Int. 506. Did you ever know this term "chronograph" to be applied to the induction balance by other persons than possibly the learned medical faculty of the Heidelberg University when conferring their diploma on Mr. Bell?

Ans. I have not.

Cross-Int. 507. Is there not a piece of apparatus well known to physical laboratories, to which the term "chronograph" is applied, and which is not an induction balance?

Ans. There is.

Cross-Int. 508. How long has such been the case?

Ans. For perhaps fifty years the term has been used. Such apparatus has been in use for at least eighty years.

Cross-Int. 509. So far as you know, did Mr. Bell ever invent *such* a chronograph?

Ans. I have no knowledge of anything of the kind.

Cross-Int. 510. Would you not regard it as an incorrect use of scientific language to apply the term "chronograph" to the induction balance?

Ans. I should, in English, as I have already said in my answer to Cross-Int. 498.

Cross-Int. 511. In what language, in your opinion, would it not be incorrect thus to designate the induction balance?

Ans. In no modern language with which I am acquainted should I regard this to be correct. I suppose it must be correct in Latin, or else the Heidelberg faculty would not have employed it.

Cross-Int. 512. When did you first see a pair of instruments made like those that are shown in Fig. 7 of Bell's first patent?

Ans. Late in May or early in June of 1879.

Cross-Int. 513. Did you know, or have you ever heard, of any such instruments being made prior to that date?

Ans. I have no knowledge on that point; nor do I recollect having heard of any such instruments prior to the time mentioned.

Cross-Int. 514. Have you ever seen a contact transmitting telephone so organized that the electrodes would with certainty break contact once, and but once, for each vibration of the diaphragm?

Ans. I have used a Reis transmitter, which appeared to operate in this manner, so far as I could judge from the effects that it produced. Of course, I cannot say that it never missed breaking, or that it never broke more than once during a single vibration; but at the time I felt confident that it operated substantially after the manner supposed in your question, and I have seen no reason to change my opinion.

Cross-Int. 515. Now, don't you know that it was absolutely impossible for you to determine, in the particular experiments to which you refer, whether the breaks were equal in number to the vibrations of the diaphragm? In other words, did you have any means at that time of counting the number of breaks and comparing it with the number of vibrations?

Ans. I will answer your two questions separately. To the first, I will reply — I do not.

As to the second — I did have at the time means by which I think I could have determined the question absolutely, if I had been studying the particular matter to which you refer. My reason for the conclusion which I have stated is, that the pitch of a note sung by the voice was reproduced, there being an apparently continuous series of sparks at the transmitter, and the quality of the sound at the receiver being of that peculiar nature which is given when the circuit is manifestly broken by a transmitter not operated by the voice. The fact that the pitch was reproduced, appears to me to show that the circuit is broken substantially once at every full vibration, although it is certainly quite possible that breaks were occasionally missed. My reason for supposing that the breaks did not in general occur more frequently than I have supposed, lies in the fact that the quality of sound was substantially the same as that which is produced by a circuit-breaker, so constructed that it cannot break the circuit with greater frequency. At the same time, I wish it to be understood that the experiments which I have in mind were not conducted with a view to studying the particular question which you propound.

Cross-Int. 516. Might you not have had the pitch of the sound reproduced, if there had been no breaks whatever?

Ans. Feebly, by microphonic action — yes; not, however, by any possibility with the loudness and quality which I obtained. However, in the experiments to which I refer, there were breaks, as manifested by the sparks as well as by the character of the sound heard at the receiver.

Cross-Int. 517. What did the sparks show as to the number of these breaks?

Ans. They showed that they succeeded each other so rapidly as to appear to the eye like a continuous light; thus showing that the number was very considerable, though not necessarily equal to the number of the vibrations of the diaphragm. They show that the breaks occur with a certain regularity; and when I have studied this phenomenon with a revolving mirror, which I did not employ in the particular experiments that I have been describing, I have found

that the sparks came at equal intervals of time, provided the circuit-breaker used was adjusted with this end in view.

Cross-Int. 518. Was there in those experiments any variation in pitch of the reproduced sound, as compared with that of the original?

Ans. In the experiments which I have in mind there was no such variation. In experiments in which any form of circuit-breaker acts upon a receiving telephone, the high upper partials which are produced will sometimes almost drown the fundamental, so that the reproduced note might almost seem higher than the original note.

Cross-Int 519. This latter phenomenon, as I understand you, did not occur in the particular experiments that you have been testifying about?

Ans. There were, of course, high overtones, but they did not prevent the reproduction of the pitch, nor my recognition of it.

Cross-Int. 520. Do you mean to say that they did not produce any variation in the pitch?

Ans. I do. By the pitch of the note, I mean, of course, the pitch of the fundamental, as I have explained in my quotation from Donkin's acoustics in my answer to Int. 7.

Cross-Int. 521. In the experiments testified to by you in the Ghegan case, in which by means of a break wheel you interrupted the primary circuit of a telephone, using an induction coil, nine or ten times a second, and yet got "speech transmitted clearly," was the pitch of the sounds of the voice reproduced?

Ans. It was.

Cross-Int. 522. How was it in those other experiments testified to by you in the Ghegan case, in which you broke a magneto circuit nine hundred times a second, and yet got speech reproduced — was the pitch of the sounds of the voice reproduced?

Ans. It was.

Cross-Int. 523. In that first set of Ghegan experiments the breaks, I suppose, were very much less numerous than the vibrations of the diaphragm?

Ans. They were.

Cross-Int. 524. And in the other set of Ghegan experiments the

breaks were much more numerous than the vibrations of the diaphragm; were they not?

Ans. Much more numerous than the fundamental vibrations.

Cross-Int. 525. And do you still think that in your experiments with the Reis instrument, last above testified to by you, the reproduction of the pitch of the original sounds was proof that the breaks were just equal in number, or substantially equal in number, to the fundamental vibrations of the diaphragm?

Ans. I do.

Cross-Int 526. Do you know of any other mechanism than the Reis telephone, in which you can with certainty break contact between the electrodes once, and once only, for each fundamental vibration of the diaphragm?

Ans. I think that this could be done with some forms of circuit-breaking transmitter, somewhat similar in construction to a Blake transmitter, but furnished with platinum electrodes under a very light normal pressure.

Cross-Int. 527. Have you ever seen or used such an apparatus?

Ans. I have tried some experiments, though not a very great many, with such an apparatus. It was not constructed with a view to test the matter regarding which you are inquiring.

Cross-Int. 528. In the Reis experiments that you have now been testifying about, and in which you assert that there was substantially one break for each full vibration of the diaphragm, you assert, among other things, that "there were, of course, high overtones" in the reproduced sound. How do you explain the presence of these overtones in the reproduced sound?

Ans. According to a well-known acoustic principle, they arise because of the sudden impulse which is given to the receiver at the moment of making the circuit, and the sudden release which is given to it at the moment of breaking the circuit. This condition is universally recognized as producing high upper partials. They are equally observed with a tuning-fork circuit-breaker, although no partials are present in the sound of the fork itself.

Direct Examination resumed.

Int. 529. Referring to Cross-Int. 515 and Cross-Int. 516, and

your answers thereto, what is the scientific value of the agreement between the pitch of sounds given out by a Reis receiver and the pitch of sounds simultaneously uttered into the Reis transmitter, as a criterion for determining the number of breaks produced by separation of the electrodes of the transmitter, when taken in connection with the characteristic differences in the loudness of sounds produced by a rapid succession of magnetic clicks in the receiver, as compared with the feeble sounds resulting from true microphonic action?

Ans. It seems to me that the fact that the pitch of the sound given out by the receiver is identical with the pitch of the sound actuating the membrane of the transmitter is sufficient to show that the circuit is broken once for each full vibration of the transmitter, since the pitch of a sound is determined entirely by the rate of vibration. And if, the number of breaks per second at the transmitter was not substantially the same as the number of full vibrations of the diaphragm, the pitch at the receiver would differ from the pitch of the sound acting upon the transmitter. I assume here that the sound is actually produced by breaking the circuit, and not by microphonic action. That this was the case in the experiments referred to, is shown by the fact that the loudness and the quality of the sound at the receiver were such as to show unquestionably that the action was a circuit-breaking and not a microphonic one.

Int. 530. Is the pitch of a sound employed as a criterion for determining the rate of recurrence of other phenomena in physical science; and, if so, will you give some familiar example analogous to that under consideration?

Ans The pitch of a sound is frequently thus employed. A familiar illustration is found in the well-known toothed wheel of Savart, in which a musical sound is produced by the striking of the teeth of the rapidly revolving wheel against a piece of card. A somewhat analogous method has been used to determine the rapidity of revolution of the revolving mirror used in Foucault's experiments to determine the velocity of light.

Int. 531. In your answer to Cross-Ints. 518 and 519, reference is made to the high upper partials which are produced by a circuit-breaker in the receiver. Are these high overtones due to the action of the receiver itself, or are they in the nature of transmitted sounds?

Ans. They are due entirely to actions going on in the receiver itself.

Int. 532. In your answer to Cross-Int. 493, you say that you have transmitted speech with a microphone instrument when the electrodes were so adjusted as not to be in contact at all, by producing between them a powerful electric arc, due to the use of a strong battery current; and you say that the speech transmitted by such apparatus was not due to microphonic action. Will you describe the experiment, and state by what mode speech was transmitted with it?

Ans. The transmitter which I used employed two electrodes of hard carbon, one of which, the hammer electrode, was firmly attached to the metallic diaphragm, while the other, the anvil electrode, was carried by a stiff metallic spring somewhat like the spring carrying the anvil electrode in the Blake transmitter, but much heavier. The pressure between the electrodes, or the distance of one electrode from the other, could be varied by means of a screw arranged to act something in the same manner as the adjusting screw acts in the Blake transmitter. This transmitter was placed in circuit with a Grove battery of from forty to sixty cells in series, the circuit also including the primary of an induction coil. The receiving telephone was placed in the secondary circuit of the induction coil in the ordinary manner. On bringing the electrodes into contact, and then allowing them to separate, an electric arc was formed between them. By means of the adjusting screw the length of the arc was gradually increased until it lost the characteristic hissing noise which is characteristic of a short arc, and became very quiet. Under these circumstances, when I spoke against the diaphragm of the transmitter, the resistance of the arc was varied by the vibrations of the hammer electrode, so that electrical undulations were set up in the circuit. A person listening at the receiver was then able to understand perfectly and without difficulty sentences which I spoke into the transmitter.

Int. 533. You have stated that this action was not microphonic. What, in your opinion, was its mode of operation, and to what class of telephone transmitters, if to any, was it analogous?

Ans. The most natural explanation is that the resistance of the arc is varied by the alternate approach and recession of the electrodes,

in which case the arc transmitter is a form of variable resistance battery transmitter. It is quite possible that there are other elements of variability concerned, but this particular point I have not especially investigated.

Int. 534. In the course of this experiment, did you try the same transmitter with various adjustments of the electrodes, both in contact and out of contact; and if so, how did the instrument behave under these varying conditions.

Ans. I tried the instrument with the electrodes in contact and under various pressures. I found that I could transmit speech microphonically, the sound becoming louder when the pressure was somewhat diminished. When I diminished the pressure very considerably, the action of the current itself tended to set up a spontaneous accidental vibration of the electrodes, which is often noticed in ordinary transmitters, and which injured the articulation; although it did not prevent the transmission of speech. Speech was transmitted without difficulty, even when under the reduced pressure the carbons were heated red-hot at the points of contact. So long as I used a moderate tone of voice under this adjustment, speech was transmitted with merely the frying noise to which I have alluded, and which is often heard with ordinary telephones. If, however, I raised my voice so as to cause the electrodes to part contact, though not breaking the current, an electric arc was formed and extinguished between the electrodes, as these parted contact and again came together. The fact that the arc was formed was evident from the brilliant light which then appeared, the room being somewhat dark. Simultaneously with this, loud noises were heard in the receiving telephone, due to the break in contact between the electrodes, and speech was entirely obliterated.

On adjusting the electrodes so that they were permanently out of contact, and then momentarily bringing them together and releasing them, an electric arc was formed between them. This arc being short, was of the unsteady, noisy character which is ordinarily known as a whistling arc. With such an arc, there were continued loud noises in the receiving telephone due to irregularities in the arc itself, so that I was unable to transmit speech under these circumstances.

(N. J. McDONOUGH.)

On increasing the length of the arc it passed from the whistling into the silent condition, the extraneous noises in the receiving telephone disappeared, and I was able to transmit speech readily.

In some experiments I have substantiated the evidence which the eye gives, that an arc was formed when I had the electrodes in very light contact and spoke to them loudly enough to break the contact by placing a high resistance galvanometer, known as a potential galvanometer, with its terminals attached, one on the one side, the other on the other side of the contact joint of the electrodes. Whenever the bright light was observed, which I have ascribed to the formation of an arc, and simultaneously with which loud noises were heard in the receiving telephone, I observed a sudden deviation of the needle of the galvanometer which indicated an increased resistance in the circuit, such as the formation of an arc would give. It is evident from the conditions of the experiment that the main current was not actually broken.

Int. 535. During the intermediate positions of adjustment of the electrodes, from the condition of actual contact between them to the condition of their separation far enough apart to form a quiet arc, what was the character of the resistance of the circuit at that place in respect to steadiness or irregular fluctuations?

Ans. The resistance of that part of the circuit under those circumstances was very variable, the arc being exceedingly unsteady and noisy.

Int. 536. And what relationship had this variability of resistance and accompanying noises to the incapacity of the instrument in that condition to transmit speech?

Ans. The electrical undulations which are necessary to transmit speech were entirely broken up by the irregular electrical pulses produced by the accidental fluctuations of the arc.

Int. 537. How does the distance between the electrodes necessary for the formation of a quiet arc compare in extent with the extreme amplitude of vibration of a microphone transmitter while transmitting speech by microphonic action?

Ans. For the formation of a quiet arc the electrodes ought to be something over $\frac{1}{32}$, say $\frac{1}{16}$ of an inch apart. It is immeasurably

greater than the extreme amplitude of vibration in microphonic action.

Int. 538. Judging from your experiments and from your knowledge of the principles of electricity and acoustics, what is the possibility of the transmission of speech by any transmitter in which the electrodes part contact at every full vibration of the diaphragm, even though the current be strong enough to remain unbroken by reason of its bridging the space between the electrodes with an arc?

Ans. All of the experiments which I have tried or heard of have led me to the conclusion that speech cannot be transmitted by such an instrument as you describe. I should be led to the same conclusion from my knowledge of electrical and acoustic principles.

Int. 539. In your answer to Cross-int. 318 you have said that the total electro-motive force in the circuit of an ordinary telephone is somewhere about $1\frac{5}{10}$ volts. About what electro-motive force is needed to produce a practically continuous electric arc; such an arc, for instance, as would be silent enough to talk through?

Ans. Not far from fifty volts, I should say, for such a silent arc; though less than this for a whistling arc. Perhaps twenty-five volts, or somewhat less, would be necessary for the continuous whistling arc.

Int. 540. In the year 1882, as appears from certain printed publications, Prof. James Blyth, of Edinburgh, described before the Royal Society certain experiments which he had made in talking through an electric arc with an apparatus constructed as follows: —

A small cylinder of carbon, having a hole bored through it axially, was firmly fixed in a metal tube. A cylindrical solid rod of carbon, with a pointed conical end projecting toward the bore of the tubular carbon cylinder, and having its axis in the same line, was held by another metal tube through which it passed tightly. The rear end of this carbon rod was embraced by a socket on the end of a screw in the same line, passing through a metal standard and having a milled head, so that the carbon rod could be moved longitudinally toward and from the carbon tube. The metal supports of the carbon rod and carbon tube respectively were insulated, and the carbons themselves were put in circuit with a magneto telephone and a battery of twenty Grove cells. Experiments were made by talking into the

open end of the carbon tube, to which was connected a flexible rubber tube provided with a mouthpiece. During these experiments the point of the carbon rod was adjusted in various positions with relation to the opposed end of the carbon tube; the point of the carbon rod being sometimes pushed forward, so as to enter the bore of the carbon tube far enough to bring the carbons into contact, and sometimes withdrawn, so as to keep the carbons entirely separated. Did you ever experiment with a similarily constructed apparatus, and if so, with what results?

Ans. I have experimented with such an apparatus. In order to be able to use a sensitive telephone receiver I placed the receiver in the secondary of an induction coil whose primary was in the direct battery circuit. When the electrodes were in contact, I could transmit speech by ordinary microphonic action; and this whether I used a single Grove cell, twenty Grove cells, or forty Grove cells. The sound was not very loud, however, as the instrument is very poorly fitted to act in this way. When I diminished the pressure, sound was still reproduced microphonically, though the portions of the carbon in contact grew red-hot. At about this pressure more or less of the frying noise was heard in the receiver. When the pressure was still further diminished, arcs were apparently formed very frequently when the instrument was strongly spoken to, and very loud noises were heard in the telephone. When these were frequent, speech was obliterated. Using forty cells of battery and separating the carbons still further, a whistling arc was produced, but it was impossible to transmit speech by means of it. On increasing the length of the arc still further it became silent, and speech was then transmitted without difficulty.

Int. 541. What are the practical disadvantages of using a magneto telephone as a receiver in the same circuit with a battery powerful enough to produce an arc, as was done by Prof. Blyth in his experiments?

Ans. A very heavy wire must be used to carry the current, so that only a comparatively small number of turns can be employed, and the instrument probably will not be sensitive.

Cross Examination resumed.

Cross-Int. 542. How close or tight contact can be made between the electrodes of a contact transmitter without destroying the capacity to transmit speech?

Ans The question is not susceptible of an exact answer, because the loss of articulation is gradual, the sound simply becoming fainter and fainter. It is possible to transmit speech with one electrode tightly screwed up against another, but I have never attempted to measure the pressure under these circumstances.

Cross-Int. 543. What other effect is produced upon the capacity of the instrument to transmit speech by increasing the intimacy of the contact between the electrodes through the medium of a screw, whereby one electrode may be screwed tightly up against the other, besides that which you have named, to wit: that the reproduced sound grows fainter and fainter as the pressure is increased?

Ans. I do not recall any other effect.

Cross-Int. 544. Can you give any clear idea as to how tightly you clamped the electrodes in the experiments described in your answer to Int. 49?

Ans. I can not, beyond the fact that they seemed firmly clamped together, so that I could not separate them from each other in the experiment described in my answer to which you refer.

[*Adjourned.*]

DECEMBER 29, 1886.

Cross-Int. 545. In your answer to Int. 538, you express the opinion that speech cannot be transmitted "by any transmitter in which the electrodes part contact at every full vibration of the diaphragm, even though the current be strong enough to remain unbroken by reason of its bridging the space between the electrodes with an arc." Please state whether speech can be transmitted by a transmitter in which the electrodes part contact, but less frequently than once for every full vibration of the diaphragm, and irrespective of whether the current be or be not strong enough to bridge the space between the electrodes during the break.

Ans. An occasional break in either of these cases will not pre-

vent the transmission of speech. As such breaks become more frequent, articulation is interfered with, and finally destroyed. I am assuming that the electrodes considered are such that they act microphonically during the time that they are in contact.

Cross-Int. 546. Supposing the breaks to become *more* frequent than one for each full vibration of the diaphragm, what effect will be produced thereby upon the capacity of the instrument to transmit speech?

Ans. I should say that the effect would not be materially different, whether the electrodes broke contact once at each full vibration or more frequently than this, so far as the transmission of speech is concerned.

Cross-Int. 547. In one of Prof. Hughes' articles on the microphone, offered in evidence by the complainants, I find the following statement: —

"The molecules at these surfaces [the surfaces of contact] being in a comparatively free state, although electrically joined, do of themselves so arrange their form, their number in contact, or their pressure (by increased size or orbit of revolution), that the increase and decrease of electrical resistance of the circuit is altered in a very remarkable manner, so much so as to be almost fabulous."

From this statement, I judge that Hughes had no settled notion as to the manner in which variations in the pressure of the electrodes of the microphone operate to vary the electrical resistance at the point of contact. Please state whether at the present time there is a substantial agreement among scientific men as to how variations in pressure in a microphone produce variations in the electrical resistance; and if not, please state whether you know how it is done.

Ans. As far as I know, there is a universal agreement among scientific men that variations in pressure between two electrodes in contact produce corresponding variations in electrical resistance. As to the particular molecular mechanism by which this is accomplished at the contact points, there is not a universal agreement, and I am not ready to say absolutely that I know precisely what goes on there.

CHAS. R. CROSS.

Attest: CHAS. H. SWAN, *Special Examiner.*

HUGHES MAY 9, 1878, ARTICLE.

From Scientific American Supplement for June 8, 1878.

[Read before the Royal Society, London, May 9, 1878.]

ON THE ACTION OF SONOROUS VIBRATIONS IN VARYING THE FORCE OF AN ELECTRIC CURRENT.

By Prof. D. E. Hughes.

Communicated by Prof. Huxley, F. R. S., etc. Received May 8, 1878.

The introduction of the telephone has tended to develop our knowledge of acoustics with great rapidity. It offers to us an instrument of great delicacy for further research into the mysteries of acoustic phenomena. It detects the presence of currents of electrity that have hitherto only been suspected, and it shows variations in the strengths of currents which no other instrument has ever indicated.

It has led me to investigate the effect of sonorous vibrations upon the electrical behavior of matter. Willoughby Smith has shown that the resistance of selenium is affected by light, and Bornstein has led us to believe that many other bodies are similarly affected. We know also that the resistance of all bodies is materially influenced by heat. Sir William Thomson and others have shown that the resistance to the passage of currents offered by wires is affected by their being placed under strains, and, inasmuch as the conveyance of sonorous vibrations induces rapid variations in the strains at different points of a wire, I believe that the wire would vary in its resistance when it was used to convey sound. To investigate this, I made a rough-and-ready telephone, with a small bar magnet four inches long, half the coil of an ordinary electro-magnet, and a square piece of ferrotype iron, three inches square, clamped rigidly in front of one pole of the magnet, between two pieces of board. When using the pendulum beats of a small French clock, or the voice, as a source of sound, I found this arrangement supplied me with an extremely delicate *phonoscope*, or sound detector.

All the experiments detailed in this paper were made with the simplest possible means, and no apparatus of any kind, constructed by a scientific instrument maker, was employed. The battery was

a simple Daniells cell, of Minotto's form, made by using three common tumblers, a spiral piece of copper wire being placed at the bottom of each glass and covered with sulphate of copper, and the glass being then filled with well-moistened clay and water. A piece of zinc, as the positive element, was placed upon the clay. Insulated wires were attached to each plate, and three of these cells were joined in series. All experiments were made on a closed circuit, the telephone being used as a phonoscope to detect variations in the current, and the consequent reproduction of sound. The apparatus or materials experimented upon were used in the same way as the transmitter of the speaking telephone of Bell. The attached sketch, Fig. 1, will make this clear. B is the battery, S the source of sound or material examined, T the telephone or phonoscope.

I introduced into the circuit at S a strained conductor — a stretched wire — listening attentively with the telephone to detect any change that might occur when the wire was spoken to, or set into transverse vibrations by being plucked aside. Gradually, till the wire broke, the strain was varied, but no effect whatever was remarked except at the moment when the wire broke. The effect was but momentary, but invariably, at the moment of breaking, a peculiar "rush" or sound was heard. I then sought to imitate the condition of the wire at the moment of rupture, by replacing the broken ends, and pressing them together with a constant and varying force by the application of weights. It was found that if the broken ends rested upon one another with a slight pressure, of not more than one ounce to the square inch on the joints, sounds were distinctly reproduced, although the effects were very imperfect.

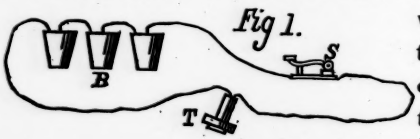


Fig 1.

It was soon found that it was not at all necessary to join two wires endwise together to reproduce sound, but that any portion of an electric conductor would do so even when fastened to a board or to a table, and no matter how complicated the structure upon this board, or the materials used as a conductor, provided one or more portions of the electrical conductor were separated, and only brought into contact by a slight but constant pressure. Thus, if the ends of the wire, terminating in two common nails laid side by side, and

separated from each other by a slight space, were electrically connected by laying a similar nail between them, sound could be reproduced. The effect was improved by building up the nails log-hut fashion, into a square configuration, using ten or twenty nails. A piece of steel watchchain acted well. Up to this point the sound or grosser vibrations was alone produced; the finer inflections were missing, or in other words the *timbre* of the voice was wanting; but in the following experiments the *timbre* became more and more perfect, until it reached a perfection leaving nothing to be desired. I found that a metallic powder, such as the white powder — a mixture of zinc and tin — sold in commerce as "white bronze," and fine metallic filings, introduced at the points of contact, greatly added to the perfection of the result.

At this point, articulate speech became clearly and distinctly reproduced, together with its *timbre;* and I found that all that now remained was to discover the best material and form, to give to this arrangement its maximum effect. Although I tried all forms of pressure and modes of contact — a lever, a spring, pressure in a glass tube sealed up while under the influence of strain — so as to maintain the pressure constant, all gave similar and invariable results, but the results varied with the materials used. All metals, however, could be made to produce identical results, provided the division of the metal was small enough, and that the material used does not oxidize by contact with the air filtering through the mass. Thus platinum and mercury are very excellent and unvarying in their results, while lead soon becomes of such high resistance, through oxidation upon the surface, as to be of little or no use.

A mass of bright round shot is peculiarly sensitive to sound while clean, but as the shot soon become coated with oxide, this sensitiveness ceases. Carbon again, from its surface being entirely free from oxidation, is excellent; but the best results I have been able to obtain at present have been from mercury in a finely divided state. I took a comparatively porous non-conductor, such as the willow charcoal used by artists for sketching, heating it gradually to a white heat, and then suddenly plunging it in mercury, The *vacua* in the pores, caused by the sudden cooling, became filled with innumerable minute globules of mercury, thus, as it were, holding the mercury

in a fine state of division. I have also tried carbon, treated in a similar manner, with and without platinum deposited upon it from the chloride of platinum. I have also found similar effects from the willow charcoal heated in an iron vessel to a white heat, and containing a free portion of tin, zinc, or other easily evaporized metal. Under such conditions the willow carbon will be found to be metallized, having the metal distributed throughout its pores in a fine state of division. Iron also seems to enter the pores, if heated to a white heat without being chemically combined with the carbon as in graphite, and indeed some of the best results have been obtained from willow charcoal, containing iron in a fine state of division.

Pine charcoal, treated in this manner (although a non-conductor as a simple charcoal), has high conductive powers, due to the iron, and from the minute division of the iron in the pores is a most excellent material for the purpose.

Any one of these preparations, confined in a glass tube or a box, and provided with wires for insertion in a circuit, I call a "transmitter."

Reis, in 1860, showed how, by the movement of a diaphragm, intermittent voltaic currents could be transmitted, agreeing in exact number with the sonorous waves impinging on the diaphragm, and thus reproducing music at a distance, by causing an electro-magnet to vibrate in unison with the diaphragm; and with an iron diaphragm, Graham Bell showed how the vibrations of that diaphragm in front of a polarized electro-magnet could similarly induce magneto-currents, corresponding in number, amplitude and form with the sonorous vibration, and thus reproduce all the delicacies of the human voice. Edison and others have produced variations in the strengths of a constant current, by causing the diaphragm to press directly upon some elastic conductor, such as carbon, spongy platinum, etc., the varying pressure upon these materials varying the resistance of the circuit, and consequently, the strength of current flowing. Graham Bell and others have produced the same effect, by causing the vibrations of the diaphragm to vary the electro-motive force in the circuit. It will be seen, however, that in the experiments made by myself the diaphragm has been altogether discarded, resting as it does upon the changes produced by molecular action, and that the variations in the strengths of the currents flowing are

produced simply and solely by the direct effect of the sonorous vibrations.

I have found that any sound, however feeble, produces vibrations which can be taken up by the matter interposed in the electrical circuit. Sounds absolutely inaudible to the human ear affect the resistance of the conductors described above. In practice, the effect is so sensible that a slight touch on the board by the finger nail, on which the transmitter is placed, or a mere touch with the soft part of a feather, would be distinctly heard at the receiving station. The movement of the softest camel-hair brush on any part of the board is distinctly audible. If held in the hand several feet from a piano, the whole cords — the highest as well as the lowest — can be distinctly heard at a distance. If one person sings a song, the distant station, provided with a similar transmitter, can sing and speak at the same time, and the sounds will be received loud enough for the person singing to follow the second speech or song sent from the distant end.

Acting on these facts, I have also devised an instrument suitable for magnifying weak sounds, which I call a *microphone*. The microphone, in its present form, consists simply of a lozenge-shaped piece of gas carbon, one inch long, quarter inch wide at its centre, and one eighth of an inch in thickness. The lower pointed end rests as a pivot upon a small block of similar carbon; the upper end, being made round, plays free in a hole in a small carbon block, similar to that at the lower end. The lozenge stands vertically upon its lower support. The whole of the gas carbon is tempered in mercury, in the way previously described, though this is not absolutely necessary. The form of the lozenge-shaped carbon is not of importance, provided the weight of this upright contact piece is only just sufficient to make a feeble contact by its own weight. Carbon is used in preference to any other material, as its surface does not oxidize. A platinum surface in a finely divided state is equal, if not superior, to the mercurized carbon, but more difficult and costly to construct. I have also made very sensitive ones entirely of iron.

The best form and material for this instrument, however, have not yet been fully experimented on. Still, in its present shape, it is capable of detecting very faint sounds made in its presence. If a

pin, for instance, be laid upon or taken off a table, a distinct sound is emitted, or if a fly be confined under a table-glass, we can hear the fly walking, with a peculiar tramp of its own. The beating of a pulse, the tick of a watch, the tramp of a fly, can thus be heard at least a hundred miles distant from the source of sound. In fact, when further developed by study, we may fairly look for it to do for us, with regard to faint sounds, what the microscope does with matter too small for human vision.

It is quite evident that these effects are due to a difference of pressure at the different points of contact, and that they are dependent for the perfection of action upon the number of these points of contact. Moreover, they are not dependent upon any apparent difference in the bodies in contact, but the same body, in a state of minute subdivision, is equally effective. Electrical resistance is a function of the mass of the conductor, but sonorous conduction is a function of the molecules of matter. How is it, therefore, that a sonorous wave can so affect the mass of a conductor as to influence its electrical resistance? If we assume a line of molecules, we know that a sonorous wave is accompanied by alternate compressions and rarefactions. If we isolate the part under compression from the part under dilatation, we vary the dimensions of the mass, and we alter its electrical resistance. In any homogeneous conductor of finite dimensions, the effect of the one will exactly compensate for the effect of the other, and we get no variation of current; but if we break up this homogeneous conductor into a series of minute subdivisions, without actually breaking their electrical continuity, we destroy this neutralizing influence, and we render evident the effect of sonorous vibrations in varying the dimensions of the mass of the conductor, and therefore in varying its electrical resistance, for we reduce the length of a portion of the conductor to a fraction of the length of a sonorous wave. Molecular action, alone, explains to me all the effects produced. Size or shape does not effect them. A piece of willow charcoal the size of a pin's head is quite sufficient to produce articulate speech. I regard the action as follows: If we have two separate conductors, joined simply by contact, this contact offers a certain resistance. Now, we can vary or lesson the resistance by increasing the pressure, thus bringing more points in contact, or closer

proximity. Now, as I employ a constant pressure on the contact, which is exactly under the same influence of the vibrations as the points of contact, more points, or closer proximity, can only be obtained through the molecular swelling or movement of the contact points.

If we assume a line of molecules at the point of contact of the minute masses of conducting matter in their neutral condition to be arranged thus, OOOOO they will appear thus under compression, OOOOO and thus under dilatation, OOOOO In the former case the electrical resistance would be *less*, and in the latter case *more*, than in the normal condition. Hence we should get variation in their electrical resistance, and thus sonorous waves could vary the strength of an electric current, and the variations of the electric current can be made to reproduce sonorous vibrations. These, however, would only produce the result in a certain line, say horizontal; but those perpendicular, while producing the same result, would be a half vibration behind, and thus if two contacts, the one horizontal and the other perpendicular, were on the same piece of charcoal and the conducting line joined to both, we should have interference. The contrary takes place, as the more contacts we have, and the more varied their direction on the same, the louder and purer the sound becomes. Hence there is no interference, and consequently the whole mass must swell and diminish equally in all directions at the same instant of time.

The tube transmitter, which I exhibit this evening, consists of an exterior glass tube two inches long and one quarter of an inch in diameter. In it are four separate pieces of willow charcoal, each one quarter of an inch long, and two terminals of the same material. The terminals are fastened in the tube, and connect exteriorly with the line and interiorly with the four loose pieces, thus: —

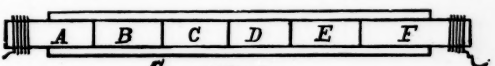


Fig. 2.

Here A is made to press on B, C, D, E, and F, until the resistance offered to the electrical current is about one third that of the line upon which it is to be employed. It may be attached to a resonant board by the ends A or F. If the result was simply due to vibrations,

we should have A and B making greater contact at a different time from E and F, and consequent interference. If it was a simple shaking or moving of B, C, D, E, and F, it could produce no change, as if B pressed more strongly on C, it would be less on A, and also if the tube was attached by the centre we should have no effect; but if the effect is due to a swelling or enlargement of B, C, D, E, F, it would make no difference where it is attached to the resonant board, as is actually the case. Again, reduce the pressure of A upon B, etc., until they are not in contact, and no trace of current can be perceived by shaking the tube. The instant the sonorous vibrations pass in the tube there is electric contact to a remarkable degree, which could only have taken place by the molecules enlarging their sphere under the influence of the sonorous vibrations.

It is impossible to say what can be the applications of the effects of the discovery which I have had the honor of bringing before the Royal Society, for the whole question has been studied with crude materials, and scarcely sufficient time has elapsed to enable me to consider its ultimate uses. I do not desire to assert that there is anything in what I have brought forward that is superior to or equal to other transmitters used for telephony. It is as loud and far more sensitive than any I have yet heard, and it may be increased by multiplication of transmitting contacts in quantity or intensity; the loudness is at present limited by the capability of the receiver. The materials at my disposal, and the arrangement of them, have not yet been sufficiently studied. I only wished to show that it is possible to transmit clear and intelligent articulate speech, and to render audible sounds which have hitherto been inaudible, by the mere operation of sonorous vibrations upon the conducting power of matter. My warmest thanks are due to Mr. W. H. Preece, electrician to the Post Office, for his appreciation of the importance of the facts I have stated, and for his kind counsel and aid in the preparation of this paper.

I do not intend to take out a patent, as the facts I have mentioned belong more to the domain of discovery than invention. No doubt inventors will erelong improve on the form and materials employed. I have already my reward in being allowed to submit my researches to the Royal Society.

From *The London, Edinburgh, and Dublin Philosophical Magazine and Journal of Science*, Vol. VI., Fifth Series, July, 1878, pp. 44-50.

ON THE PHYSICAL ACTION OF THE MICROPHONE.*

BY PROFESSOR HUGHES.

In the paper read on the 9th of May, before the Royal Society, I gave a general outline of the discoveries I had made, the materials used, and the forms of microphone employed in demonstrating important points. I have made a great number of microphones, each for some special purpose, varying in form, mechanical arrangement and materials. It would require too much time to describe even a few of them, and as I am anxious in this paper to confine myself to general considerations, I will take it for granted that some of the forms of instrument and the results produced are already known.

The problem which the microphone solves is this: To introduce into an electrical circuit an electrical resistance, which resistance shall vary in exact accord with sonorous vibrations, so as to produce an undulatory current of electricity from a constant source, whose wave-length, height and form shall be an exact representation of the sonorous waves. In the microphone we have an electric conducting material, susceptible of being influenced by sonorous vibrations, and thus we have the first step of the problem.

The second step is one of the highest importance. It is essential that the electrical current flowing be thrown into waves of determinate form, by the sole action of the sonorous vibrations. I resolved this by the discovery that when an electric conducting matter in a divided state, either in the form of powder, filings, or surfaces, is put under a certain slight pressure, far less than that which would produce cohesion and more than would allow it to be separated by sonorous vibrations, the following state of things occurs: The molecules at these surfaces being in a comparatively free state, although electrically joined, do of themselves so arrange their form, their number in contact, or their pressure (by increased size or orbit of revo-

* Communicated by the Physical Society, having been read June 8, 1878.

lution), that the increase and decrease of electrical resistance of the circuit is altered in a very remarkable manner, so much so as to be almost fabulous.

The problem being solved it is only necessary to observe certain general considerations to produce an endless variety of microphones, each having a special range of resistance.

The tramp of a fly or the cry of an insect requires little range, but great sensitiveness; and two surfaces, therefore, of chosen materials under a very slight pressure, such as the mere weight of a small superposed conductor, suffice; but it would be unsuitable for a man's voice, as the vibrations would be too powerful, and would, in fact, go so far beyond the legitimate range, that interruptions of contact amounting to the well-known "make and break" would be produced.

A man's voice requires four surfaces of pine charcoal, as is described in my paper to the Royal Society, six of willow charcoal, eight of boxwood, and ten of gas carbon. The effects, however, are far superior with the four of pine, than with either the ten of gas carbon or any other material, as yet used. It should be noted that pine wood is the best resonant material we possess; and it preserves its structure and quality, when converted into the peculiar charcoal I have discovered and described.

It is not only necessary to vary the number of surfaces and materials, in accordance with the range and power of the vibrations, but these surfaces and materials must be put under more or less pressure, in accordance with the force of the sonorous vibrations. Thus for a man's voice, the surfaces must be under a far greater pressure than for the movements of insects. Still, the range of useful effect is very great, as the boxes which I have specially arranged for a man's voice are still sensitive to the tick of a watch.

In all cases it should be so arranged that a perfect undulatory current is obtained from the sonorous vibrations of a certain range. Thus, when speaking to a microphone transmitter of human speech, a galvanometer should he placed in the circuit, and while speaking, the needle should not be deflected, as the waves of + and — electricity are equal, and are too rapid to disturb the needle, which can only indicate a general weakening or strengthening of the current. If the pressure on the materials is not sufficient, we shall have a

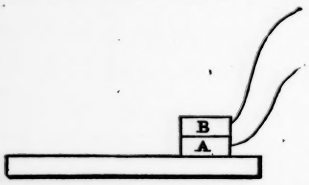
constant succession of interruptions of contact, and the galvanometer needle will indicate the fact. If the pressure on the materials is gradually increased, the tones will be loud but wanting in distinctness, the galvanometer indicating interruptions; as the pressure is still increased, the tone becomes clearer, and the galvanometer will be stationary when a maximum of loudness and clearness is attained. If the pressure be further increased, the sounds become weaker, though very clear; and as the pressure is still further augmented, the sounds die out (as if the speaker were talking and walking away at the same time), until a point is arrived at where there is complete silence.

When the microphone is fixed to a resonant board, the lower contact should be fixed to the board, so that the sonorous vibrations act directly on it. The upper contact, where the pressure is applied, should be as free as possible from the influence of the vibrations, except those directly transmitted to it by the surfaces underneath; it (the upper surface) should have its inertia supplemented by that of a balanced weight. This inertia I find necessary, to keep the contact unbroken by powerful vibrations. No spring can supply the required inertia; but an adjustable spring may be used to ensure that the comparatively heavy lever shall duly pre-s on the contacts.

The superposed surfaces in contact may be screwed down by an insulated screw passing through them all, thus doing away with the lever and spring; but this arrangement is far more difficult to adjust, and the expansion by heat of the screw causes a varying pressure. It is exceedingly simple, however, easily made, and illustrates the theoretical conditions better than the balanced lever I have adopted in practice.

In order to study the theoretical considerations, and that with the most simple form of microphone, freed from all surrounding mechanisms, let us take a flat piece of charcoal two millimeters thick and one centimeter square, and after making electrical contact by means of a copper wire on the lower surface, glue that to a small resonant board, or better for the purpose of observation, to a block of wood ten centimeters square. Upon this superpose one or more similar blocks of charcoal, the upper surface in communication with a wire,

the lowermost surface resting flat, or as nearly so as possible, on the lower block. The required presssure is put on the upper block; and while in this state the two may be fastened together with glue at the sides, or, better, by an insulated screw. The pressure can then be removed, as the screw or glue equally preserves the force. Let the lower piece be called A, and the upper B; when we subject this board to sonorous vibrations, we cannot imagine an undulatory movement of the actual wave-length in such a mass, that is a length comparable with the real wave-length of the sonorous wave, which may be several feet. Nor can we imagine a wave of any length, without admitting that the force must be transmitted from molecule to molecule throughout the entire length; thus any portion of a wave, of which this block represents a fraction, must be in molecular activity.



The lower portion of the charcoal A, being part of the block itself, has this molecular action throughout, transmitting it also to the upper block. How is it that the molecular action at the surfaces of A and B should so vary the conductivity or electrical resistance as to throw it into waves in the exact form of the sonorous vibrations? It cannot be because it throws up the upper portion, making an intermittent current, because the upper portion is fastened to the lower, and the galvanometer does not indicate any interruption of current whatever. It cannot be because the molecules arrange themselves in stratified lines, becoming more or less conductive, as then surfaces would not be required; that is, we should not require discontinuity between the blocks A and B; nor would the upper surface be thrown up if the pressure be removed, as sand is on a vibrating glass. The throwing up of this upper piece B, when pressure is removed, proves that a blow, pressure, or upheaval of the lower portion takes place; that this takes place there cannot be any doubt, as the surface, considered alone (having no depth), could not bodily quit its mass. In fact there must have been a movement to a certain depth; and I am inclined to believe, from numerous experiments, that the whole block increases and diminishes in size at

all points, in the centre as well as the surface, exactly in accordance with the form of the sonorous wave. Confining our attention, however, to points on A and B, how can this increased molecular size or form produce a change in the electrical waves? This may happen in two ways: *first*, by increased pressure on the upper surface, due to its enlargement; or, *second*, the molecules themselves, finding a certain resistance opposed to their upward movement, spread themselves, making innumerable fresh points of contact. Thus an undulatory current would appear to be produced by infinite change in the number of fresh contacts. I am inclined to believe that both actions occur, but the latter seems to me the true explanation, for if the first were alone true, we should have a far greater effect from metal powder, carbon, or some elastic conductor, such as metallized silk, than from gold, or other hard, unoxidizable matter; but, as the best results as regards the human voice were obtained from two surfaces of solid gold, I am inclined to view with more favor the idea that an infinite variety of fresh contacts brought into play by the molecular pressure, affords the true explanation. It has the advantage of being supported by the numerous forms of microphone I have constructed, in all of which I can fully trace the effect.

I have been very much struck by the great mechanical force exerted by this uprising of the molecules under sonorous vibrations. With vibrations from a musical box two feet in length, I found that one ounce of lead was not sufficient on a surface of contact one centimeter square to maintain constant contact; and it was only by removing the musical box to a distance of several feet, that I was enabled to preserve continuity of current with a moderate pressure. I have spoken to forty microphones at once, and they all seemed to respond with equal force. Of course there must be a loss of energy in the conversion of molecular vibrations into electrical waves; but it is so small that I have never been able to measure it with the simple appliances at my disposal. I have examined every portion of my room, — wood, stone, metal, in fact, all parts, — and even a piece of india-rubber: all were in molecular movement whenever I spoke. As yet I have found no such insulator for sound as gutta-percha is for electricity. Caoutchouc seems to be the best; but I

have never been able, by the use of any amount at my disposal, to prevent the microphone reporting all it heard.

The question of insulation has now become one of necessity, as the microphone has opened to us a world of sounds, of the existence of which we were unaware. If we can insulate the instrument so as to direct its powers on any single object, as at present I am able to do on a moving fly, it will be possible to investigate that object undisturbed by the pandemonium of sounds which at present the microphone reveals where we thought complete silence prevailed.

I have recently made the following curious observation. A microphone on a resonant board is placed in a battery-circuit, together with two telephones. When one of these is placed on the resonant board, a continuous sound will emanate from the other. The sound is started by the vibration which is imparted to the board when the telephone is placed on it; this impulse, passing through the microphone, sets both telephone-disks in motion; and the instrument on the board, reacting through the microphone, causes a continuous sound to be produced, which is permanent so long as the independent current of electricity is maintained through the microphone. It follows that the question of providing a *relay* for the human voice in telephony is thus solved.

The transmission of sound through the microphone is perfectly duplex; for if two correspondents use microphones as transmitters and telephones as receivers, each can hear the other, but his own speech is inaudible; and if each sing a different note, no chord is heard. The experiments on the deaf have proved that they can be made to hear the tick of a watch, but not, as yet, human speech distinctly; and my results in this direction point to the conclusion that we only hear ourselves speak through the bones and not through the ears.

However simple the microphone may appear at first glance, it has taken me many months of unremitting labor and study, to bring to its present state through the numerous forms each suitable for a special object. The field of usefulness for it widens every day. Sir Henry Thompson has succeeded in applying it to surgical operations of great delicacy, and by its means splinters, bullets, in fact all foreign matter, can be at once detected. Dr. Richardson and myself

have been experimenting in lung and heart diseases; and although the application by Sir H. Thompson is more successful, I do not doubt that we shall ultimately succeed. There is also hope that deafness may be relieved. For telephony articulation has become perfect, and the loudness increased. Duplex and multiplex telegraphy will profit by its use, and there is hardly a science where acoustics has any direct or indirect relation which will not be benefited. And I feel happy in being able to present this paper on the results obtained by a purely physical action to such an appropriate and appreciative body as the Physical Society.

In conclusion, allow me to state that throughout the whole of my investigations I have used Prof. Bell's wonderfully sensitive telephone instrument as a receiver, and that it is owing to the discovery of so admirable an appliance that I have been enabled to commence and follow up my researches.

PREECE LECTURE, ETC., MAY 23, 1878.

ARTICLE ENTITLED "CONNECTION BETWEEN SOUND AND ELECTRICITY."

A Lecture delivered by Mr. William H. Preece, before the Society of Telegraph Engineers, May 23, 1878, and printed in the Journal of that Society, Vol. II., page 270.

THE PRESIDENT: I have now the pleasure to call upon Mr. William Preece to favor us with his lecture on "The Connection between Sound and Electricity."

MR. W. H. PREECE: Mr. President, a late member of the present Ministry, at a dinner given by the Institution whose hospitality we experience in this hall, implied, on the authority of one of the leading members of the engineering profession, that invention, like cocktails and Colorado beetles, had taken root in America and had deserted old England. It is therefore to me, as I am sure it is to you, a great gratification to have brought before us an invention which is the offspring of British soil. During the last few months the science of acoustics has made marvellous and rapid strides. First of all we had the telephone, which enabled us to transmit human speech to distances far beyond the reach of the ear and the eye. Then we had the phonograph, which enabled us to reproduce sounds uttered at any place and at any time; and now we have that still more wonderful instrument which not only enables us to hear sounds that would otherwise be inaudible, but also enables us to magnify sounds that are audible; in other words, the instrument which I shall have the pleasure of bringing before you to-night is one that acts towards the ear in the same capacity that the microscope acts towards the eye.

I may point out in the first instance, that the telephone and the phonograph depend essentially upon the fact — and a great fact it is — that the mere vibration of a diaphragm can reproduce all the tones of the human voice. In the telephone, the voice is also made to vibrate a diaphragm, which, by completing an electric circuit, or by varying a magnetic field, or by altering the resistance or electromotive force of the circuit, produces effects at a distance which re-

sult in the reproduction of the motion of the diaphragm; but in this new instrument diaphragms are cast aside, and we have the direct conversion of sonorous vibrations or sound-waves into forms of electrical action.

Now if it had been the habit or custom of this Society, to give to the papers and discourses delivered here sensational titles, I should have been inclined so call the few remarks I am going to make to-night "A Philosopher Unearthed." Professor Hughes is well known to us all. He has been more or less associated with this Society since its first inception. Whenever he is in London he is always amongst us. His instrument is well known to us as one of the most exquisite pieces of mechanism ever invented, and his works, though few, are known because they are sound.

The chief characteristic of this philosopher whom I have succeeded in unearthing is his extreme modesty. If he had been left to himself I do not think we should even have had the microphone here; but by a lucky chance he recently admitted me into his secret, and I am enabled to-night to bring before you the results of his labors, and they have been labors indeed. For months and months he has been working and striving at the ideas which at last he has elaborated into the microphone.

Now, the chief characteristic of the apparatus I am going to introduce to you to-night is its great homeliness, its uncouth roughness, and its absurd simplicity. With common nails, with small pieces of wood, with halfpenny money boxes, with plain sealing-wax, with the ordinary apparatus which every child has at its command, he has been able to attack nature in her stronghold, to ask her questions, and receive back answers, and lay bare to us facts and thoughts which, though they have existed from time immemorial, are brought to light now for the first time.

Now let us, in the first place, ask ourselves this question. What is sound? It is a very difficult question to answer, in the short time at my disposal; but it is necessary I should first say something to you about the nature of sound, and then say something about the nature of electricity, and show you how the one can be converted into the other.

Now, what is sound? While I am speaking to you I am setting

the air in this room into vibration. The air of this room is composed of an infinite number of infinitely small molecules; every molecule is set into motion and vibrates to and fro, backwards and forwards, like the bob of a pendulum, and between my mouth and every one of the ears in this hall there is a rapid but short excursion to and fro of every single molecule that composes the atmosphere of this room, and it is the impinging of these molecules against the drum of the ear that produces that sensation called *sound*. But more than that, not only is the air of this room in this marvellous state of motion, but every piece of wood, every wall, every picture — everything in this hall at this moment — is almost, I may say, alive; trembling away, moving backwards and forwards, forming what are called sonorous vibrations. If the sound be loud enough, and the note deep enough, we can distinctly feel these vibrations. Sound is therefore the vibration, in particular periods and particular phases, of matter.

Now, what is electricity? Faraday, the greatest electrician, perhaps, that ever lived, was asked that question, and he said the more he studied electricity, the more he unravelled its mysteries, the more mystified he became as to its source and its origin; therefore, it seems an act of impudence, on the part of myself, or anybody else, to attempt to answer the question, What is electricity? But great strides have occurred since the days of Faraday; we know a great deal more now of the internal molecular action of bodies; we know that light and heat and sound are the mere action of those molecules of which matter is composed; and we feel sure, from the facts brought to our notice by the delicate apparatus of the present day, that electricity is simply a mode of motion, nothing more nor less than the simple play of the molecules of matter. The truth of this will be made evident to-night by the wonderful connection which exists between sound, which we know to be merely a mode of vibration, and electricity, which will reproduce to us the effects of sound.

To make this evident to us, we must have two instruments; the one a detector, which will render apparent to us any electrical action that shall result in sound; and it fortunately happens that this marvellous telephone is an instrument of such extreme delicacy that it has made us acquainted with *currents* of electricity hitherto unknown, though

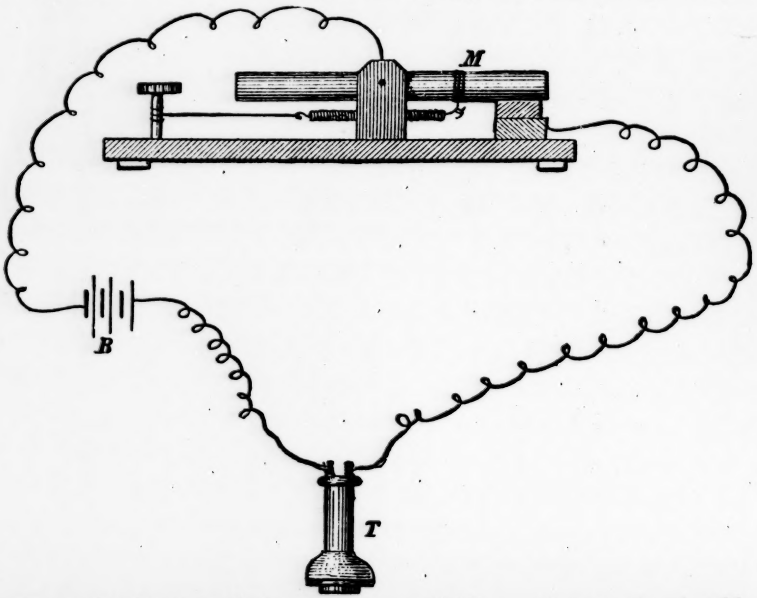
their presence has been suspected. The telephone which Professor Hughes has used in his researches is as simple in its construction as are all his other apparatus. It consists of two rough pieces of board clamped together. There is half the end of an electro-magnet that probably has been in his possession since his early experiments, to judge from its appearance. The magnet is a piece of steel rod that has been magnetized. The wire used, and which he has found extremely useful to him, is wire that was originally made for very different purposes — for ladies' bonnets — and in front of this is placed a piece of ferrotype iron, well known by those who have experimented with the telephone.

But what is the source of sound? It was necessary in making these experiments that he should have a source of sound, something which would generate those sonorous vibrations of which I have spoken. This source of sound was a small mantelpiece clock of French manufacture, which cost originally three or four francs. It has been in use many years, and has been in many parts of the world. It is repaired with great lumps of sealing-wax; but nevertheless it has or ought to have a pendulum, which gives a succession of beats, and those beats form a source of sound. Now, with this source of sound, and this beautiful scientific apparatus, the telephone, as a detector, he started upon one of Sir William Thomson's discoveries, viz., that wires alter their electrical condition when they are placed under strain. He took a piece of wire, applied weights to it, connected the clock with it, and heard nothing. He was not disconcerted; he applied weight after weight till he reached the breaking strain of the wire, and at the moment when the wire broke, he heard a rush or sound which he thought was an indication of what he was searching for; so he took the two ends of his wire and laid them together, placed his sources of sound above them, and to his intense delight heard — what imagination perhaps assisted him in believing to be a tick. He thought he was on the right track, and he then manufactured, with a flat piece of brass for a lever, a pin for an axle, sealing-wax for cement, black wax for solder, and the uncovered bonnet wire for binding, a little apparatus which enabled him to apply constant pressure to the thing he was experimenting upon; in

fact, by this means he was enabled to produce what we electricians call a "bad joint."

To his intense delight he found with this bad joint, and rough, application of pressure by putting various things — pieces of metal, chain, etc. — underneath this little contrivance, he was able to obtain sonorous effects. But this contrivance, simple as it appears, was a great deal too elaborate and complicated for his purpose; so he took two French nails — little bright nails, so much used in France — laid them side by side, not touching each other, and bringing the ends of the wire in contact with them, and laying between or across them a third and similar nail, he was able to reproduce almost perfectly the sound of the clock, and, more than that, he began to get indications of the sound or tone of the voice. He then used chains; he took a gold chain, and put it beneath his little compressor, and with that he was able to speak with great ease. From that he tried filings, and found with matter in a finely divided state he was able to reproduce all the effects of sound. At last he made little glass tubes, about two inches long, filling them with white bronze powder which artists use, which is a mixture of zinc and tin, and he was able to reproduce exactly the tones of the voice. But in his experiments with carbon he was able to make what may be called quite an independent and another discovery. The carbon he experimented with was the common carbon used by artists in sketching their drawings, and this carbon he found to be a non-conductor of electricity. The idea struck him that this non-conductor of electricity might be made a conductor, and by various processes he at last arrived at a plan of boiling or heating this carbon in quicksilver. Carbon so heated in an atmosphere of quicksilver, itself becomes permeated through and through with quicksilver, and by that means we get the mercury subdivided into an almost infinitely pure state. Probably mercury in this state as closely approaches the molecular as anything can do; there is no apparent indication of mercury under the microscope, and yet we know that the carbon has been mercurized, because it is converted from a complete insulator into a conductor, and it has a metallic ring when it falls. Now, then, having by these processes arrived at a substance which is remarkably sensitive to all the variations of the sound of the human voice, his next task was to construct these things

into such a form as to make them telephonic transmitters. For that purpose he brought to his aid a very cheap kind of apparatus, a half-penny money box. Inside this he placed his carbon transmitter; and as this discovery is not fenced in by fear of the patent or any other law, I am quite sure you will be glad to know how to make a Hughes transmitter. First, he takes a piece of one-quarter-inch board about two inches long and one inch broad, and he raises upon that two thin brass bearings, with a hole worked through by means of a pin for the support of his axis. He then takes a piece of carbon about two inches long, which has been mercurized, which has a pin cemented to it near its centre, which acts as an axis, and makes it into a lever. On the board he places another smaller piece of carbon, similarly treated, and upon this rests another similar-sized piece of carbon, the two being connected by a piece of paper. (See figure in which M represents the transmitter, B the battery and T the telephone.)



Now the battery is another remarkable specimen of scientific manufacture. Three little glass tumblers are taken; at the bottom of each a piece of copper wire is coiled spirally. The copper wire is covered with a little sulphate of copper. The tumbler is then

filled with moistened clay, and upon the top of this clay is placed a piece of scrap zinc. The three cells are placed in a cigar box. The tube transmitter consists of a glass tube about two inches long and one-fourth inch diameter, inside which several pieces of mercurized carbon are inserted, touching each other with a pressure regulated by a screw fixed to each end. The size of the carbon appears to be of little consequence. He has produced effects with carbon not larger than the head of a pin. We shall show this by and by; but rather than disturb the order of these researches, I think it advisable in the next place to show you how this principle has been carried a little further to produce what he calls the microphone. This apparatus is extremely sensitive. It will give evidence of nearly any sound; but in the microphone itself, which I have here, this extreme sensitiveness is carried to a still further extent. In point of fact this is a microphone; but in this particular instance, the pressure bearing between the two carbons is regulated by a spring, and it is so regulated that the transmitter is independent of any position in which it may be held. It is free to be moved in any direction, in consequence of the pressure of the spring; but in one form of instrument this spring is dispensed with, and the pressure between the carbons is reduced to its greatest sensitiveness by making the two arms of this lever as short as possible; but in the first machine he used, a piece of carbon was fixed on the top of an upright board of that kind, and a smaller piece was fixed down below. A cup-shaped ball was made at one end, and a similar one at the bottom, resting upon a piece of lozenge-shaped carbon; and this lozenge-shaped piece of carbon rests with the greatest nicety upon its lower disc, and is just in that position of equilibrum that the slightest atmospheric disturbance produces the effects which we are now about to show you.

I think it desirable to tell you that you must not expect to-night distinct articulations. We have made a violent effort to make these experiments evident to you all.

Now, the effects you have just heard have been produced by a microphone similar to that drawn on the board. We will now repeat the effects with the machine on the table, and in order that you may judge of the effect — for Professor Hughes desires you should see there is no deception — we will connect this up, and use

his old friend, the clock, to make its ticks, if it will, evident over the whole room. One of the greatest effects which this instrument produces, is to render evident the tramp of a fly, and we have some nice little captives with which we will demonstrate that effect at the close of the meeting, (*Illustration with clock.*)

To show that the sounds come from the clock itself, Professor Hughes will lift up the clock, when all traces of sound will have disappeared, and on putting it down again, the sounds will be produced; so that the sound you hear is the sound of that clock, which has been magnified.

Now, we have here a common quill pen, and Professor Hughes will do as they do on the stage, pretend to write a letter, and I have no doubt if you listen attentively, you will hear the scratching of his pen. (*Illustrated.*)

Now, there are some peculiarities in this apparatus that are very striking. In the first place, though the sounds produced are very great, they do not interfere with each other, If you have a friend at the other end speaking to you, you can hear his voice distinctly working through your voice, and the result is, you get a duplex action. Two or three persons can talk to each other without impediment or confusion.

Yet another point is, that the articulation is absolutely perfect. One of the great difficulties, both in the telephone and the phonograph, is getting the noises and sibilant sounds reproduced, such as *s* and *c* and *sh*, which are produced by such extremely minute variations in the sonorous vibrations that they are lost in those instruments. Thus, if through the telephone you ask a person to waltz, it will come out "walk," and names like my own, with the sound of *s* in it, though it is spelt with a *c*, would come out "Pree," not Preece. In this transmitter, one of its chief peculiarities is the fact that all sounds are faithfully reproduced, and it tends very much to upset the notion — Helmholtz's theory — that vowel sounds, and other sounds, are due to the superposition of waves upon waves of tones and overtones. This apparatus shows, almost unquestionably, that all these different properties, all these effects of intonation, are due to differences in the form of the wave sent. Another peculiarity is this. I have told you that all in this room,

every one's body while I am speaking, is alive with sound. If you take this transmitter and place it in front of your mouth, or put it on your forehead, or on the top of your head, or put it in your pocket, or upon your breast, it will still transmit sounds to distant places. Put it in a room, it does not matter where, it will reproduce the sounds. Put it anywhere in a drawing-room where there is a piano, you will hear the sounds of the piano faithfully reproduced. It is, as you see, a marvellously rough affair; you may throw it up, kick it about, and do what you like with it; it will always act. Here is the identical box that Professor Hughes made two or three months ago; it has never been touched; it has been always at work, and never needs repair.

These are some of the peculiarities of this instrument, and I dare say some of you would like to know a little about its theory. We have here two points in contact, and those two points in contact complete an electrical circuit. The electric current that flows through that circuit depends for its strength entirely upon the obstacles or resistances, in that circuit, to the flow of the current. Any alteration in any shape or form in the resistance of that circuit will result in the increase or decrease of the strength of the current flowing; and upon this board I will make a rough attempt to endeavor to give you an idea of what occurs. You must not conceive that these round balls are molecules themselves; they are merely meant to represent the sphere of action of each molecule at each point of contact. In a normal state the molecules rest against each other, as shown by the upper line. When, from any cause, pressure is increased, they are contracted, as shown in the second line; when, from any cause, the pressure is decreased, they expand in the form shown on the other line. While I speak at you, the air of this room is thrown into vibration, the mass of air being subdivided into molecules in compression and molecules in extension. In a long wire, these successions of compressions and extensions compensate each other; but when we break up a body into infinitely small parts, when we make contact between two bodies as shown there, we isolate the portion of the sonorous wave in compression from that in extension, the result is that we have a variation in the resistance of the line. Now this variation in resistance depends upon the compression and

dilatation of the molecules. It depends upon the tone of the voice, and the result is, the resistance of the current varies with its variation of pressure, and at the distant end we have currents varying exactly as the voice varies, and reproducing on the telephone all the effects which we have seen. Hence follows the action of the microphone, which depends upon the variation produced in the contact of bodies by the sonorous vibrations of the voice. As I am now speaking at that microphone. all the molecules of that transmitter are thrown into this elaborate series of compressions and dilatations. The current is varied; the current goes to the room below, and is reproduced upon the telephone, as we have heard. Hence the effect is due to the difference of pressure at the points of contact, as is proved by using atmospheric pressure, applying heat, making noises, and any large variation of pressure results in sound being reproduced.

No one has ever been nearer a great discovery than Mr. Edison. His telephone is based on the variation of resistance in carbon due to pressure. He used carbon and finally divided matter; but he worked on the idea that the difference in pressure was produced by the vibration of a diaphragm. Had he thrown away his diaphragm, he would have forestalled Professor Hughes in this respect, and found that the sonorous vibrations themselves produced this difference of pressure.* The great secret of Professor Hughes's discovery is that sonorous vibrations and electrical waves are to a certain extent synonymous.

Now, as to the uses to which this instrument is capable of being applied. It has been applied to surgical purposes in the form of a stethoscope. Though it does not show very markedly the beats of the heart, because they are more mechanical thumps than sonorous vibrations, yet it will show the injection and ejection of air in the lungs, and for many other surgical purposes it must become a valuable instrument. It admits us to some of the mysteries of insect life, and by its means we can hear sounds emitted by insects which have never been heard before. Going further, it has enabled the deaf to hear; deaf persons

* It appears that Mr. Edison actually did this, but he was anticipated by Professor Hughes.

who never heard a telephone before have been able to hear distinctly. It has enabled us to hear the physical operation which goes on in the process of crystallization of bodies, and other things which before were wholly inaudible, and in fact it is impossible to say to what uses it may not be put.

It is rather remarkable that in an excellent paper read before the American Electrical Society, the author, Mr. Pope, makes these curious remarks: —

"The most striking results are to be looked for in the direction first pointed out by Mr. Gray, for the reason that if an effectual method of controlling the resistance of the circuit by means of atmospheric vibrations can be discovered, the source of power, which in this case is the battery, may be augmented to any required extent. It is not to be denied that the problem thus presented is one of exceeding mechanical difficulty, but there is no reason to suppose that it may not be successfully solved. It is to the development of this variety of speaking telephone, rather than to that of the magneto instrument that inventors will find it most advantageous to turn their attention; for I hazard little in saying that the latter has already reached such a surprising degree of efficiency, as to leave comparatively little more to be done within the necessary limitations which have been pointed out."

Mr. Pope throws out as a suggestion what has now been done, with the exception of the supposed mechanical difficulty, and that has been got over by a halfpenny money box.

Now, one very pleasing and gratifying circumstance attaches to this discovery of Professor Hughes. He has thrown it open to the world, and by that means he has no doubt checked that species of immorality (I don't know what else to call it) connected with the infringement of the patent law as regards the telephone. He allows us all to manufacture microphones for ourselves; but even he has been subject to rather a peculiar incident. One impulsive and active gentleman, who was present at the Royal Society the other night when Professor Hughes first described his invention, went home and made himself a microphone, wrote a description of it, and sent it off post haste to Paris. A short time afterwards, Professor Hughes himself with great care prepared a paper to be read before the French Academy, bnt to his great surprise he found that he had been forestalled; a description of his instrument had already appeared in the Paris prints from the gentleman in question.

There are lessons to be learnt from this discovery; and the principal lesson is, we can all of us, with the means at our disposal, cross-question nature and find out her secrets, and there are many secrets which yet remain to be divulged. We learn the wonderful connection which exists between all the physical forces; heat and light, and electricity and magnetism, are all co-related; and it has come to this, that what boys have said in joke, has come to pass in earnest. We have been able to convert electricity into light, and light into electricity. We are now able to convert electricty into sound, and sound into electricity, and thus we are enabled to see the thunder and to hear the lightning.

THE PRESIDENT: We have listened to a very interesting and instructive address, and I hope it will be followed by an equally interesting discussion. I see many here who are fully able to take part in it, and, with your permission, I will call upon his Grace the Duke of Argyll to open the discussion.

THE DUKE OF ARGYLL, K. G., rose and said: Mr. President and gentlemen, — Though I am a stranger here, I am very glad of the opportunity which the kind invitation of your President gives me to say a few words as to the extreme interest with which I am sure we have all heard the admirable lecture just delivered by Mr. Preece; one which, for interest of matter and for clearness of exposition, I have never heard excelled in the course of my experience of scientific lectures. It is quite obvious that we are here in the presence of many of the most remarkable discoveries of an age which is full of discoveries; discoveries which are sure to be utilized in a thousand ways which at present we cannot foresee. Mr. Preece has said at the beginning of his lecture that he rejoices, on this occasion, at least, that the progress of this discovery has taken place on English soil. On further inquiry, however, I am not sorry to find that the distinguished man whose discovery has just been explained, is, although a resident in this country, a citizen of America; because, though I have as strong a patriotic feeling as any gentleman present in this assembly, I am one of those who, in matters of science, are thoroughly cosmopolitan in the triumphs of human intellect, by whatever nation they may be made, and further, I am one of those who feel that the citizens of America are, after all, our

fellow-countrymen. Now, with regard to the uses to which this discovery may be put, there are many which immediately suggest themselves to one's imagination.

I am sorry to hear from Mr. Preece, that the immediate application of it, in so far as it has yet been tried, to the sounds of the human heart, does not throw much additional light on that most curious matter, the circulation of the blood, because probably the sounds are of a muffled nature, and do not give rise to sonorous waves such as those which have been explained to us; but I cannot doubt for a moment that one of the most immediate applications of this very valuable discovery will be a surgical application, and that through it our medical men will be able to pronounce upon a series of diseases with which we are at present wholly unacquainted. Now, being myself accustomed to think a good deal about political affairs, I confess I was struck with some of the inconveniences which might occur through the agency of this discovery. We are now very close, you know, to Downing Street, and it occurred to me if you placed one of these little halfpenny boxes in the room where the Cabinet sits, we should have the whole of the secrets of the Cabinet revealed in this hall of the Civil Engineers (laughter); or if by any extraordinary ingenuity, such as many conjurers can command, one of these little boxes could be inserted in the pocket of my distinguished friend Count Schouvaloff or Lord Salisbury, I have no doubt we should be at this moment in possession of all those secrets which the whole of this country and of Europe are desirous to know. I should like to know from Professor Hughes that there is some means of preventing this. I remember a lady friend who was very fond of attending sermons, and she was laid up by a complaint which prevented her going to church; but she contrived to take a lodging almost under the roof of the church where a celebrated minister preached, and she had a speaking trumpet fixed near the pulpit, and by that means she was able to enjoy the sermons she so much desired to hear. But with this instrument of Professor Hughes we shall be able to poach on every one's manor, and know every one's secrets; and I should much like to know from Professor Hughes whether, since one of these little boxes set anywhere in a room is capable of transmitting to a distance all the conversation which takes place in that room, he is able to provide an antidote for it.

Dr. Lyon Playfair, M. P.: I can only sympathize with the remarks which my noble friend the Duke of Argyll has just made to us. In fact, one sees no end to the application of this discovery. I have no doubt before long Professor Hughes will connect his instrument with the aerophone which magnifies sound so that one can hear it over four or five square miles. Only conceive what might happen in a debate in which such orators as the noble duke who has just sat down or Mr. Gladstone made one of their magnificent speeches; supposing one of these instruments were connected with the aerophone, and instead of those speeches being confined to the area of St. Stephen's, they were sent over four square miles of London, and allowed millions of the public to enjoy the beneficial effects of that eloquence! It is not only possible but probable. Only conceive to what large influences such a discovery as this may lead. Or supposing you connect this instrument with the opera house, where one of our great contraltos or sopranos are singing, it would be possible by means of the aerophone to communicate it to a whole town. The development of this instrument, in connection with others already in existence, may be productive of prodigious effects. I think in the hands of the physician it will prove to be a discovery of the greatest importance and value. It occurred to me that though the muffled sounds of the heart might not be adapted for repetition, it might be possible in acute diseases, such as inflammation, or other acute diseases which proceed from too energetic action in particular parts of the body, it occurred to me that these might be detected by this agency. In the beginning of a discovery of this kind it is impossible for the most lively imagination to see the results that may flow from it; and in the hands of Professor Hughes, or in the hands of others, it is impossible to place a limit to the development which may result from the description we have heard to-night. I consider it one of the most remarkable discoveries of modern times, and I congratulate Professor Hughes upon it. He is a citizen of a country to which I am dearly attached by many acts of kindness shown to me; at the same time he has been so long connected with this country, that we may fairly claim this as the joint discovery of two great nations.

Mr. Willoughby Smith: Marvellous discoveries have been

brought before us lately in such quick succession, that I am pleased we have at length an opportunity to pause and reflect on what we have already seen and heard. I cannot agree with Mr. Preece in his molecular and sound-wave theory of the microphone. I believe the phenomena to be solely due to what is known as a varying contact, and that the microphone is nothing more than a sensitive commutator. Mr. Preece has told us that by the aid of the microphone the tramp of a fly can be heard, resembling that of a horse walking over a wooden bridge; but I can tell you something which, to my mind, is still more wonderful; that by the aid of the telephone I have heard a ray of light fall on a bar of metal. This may appear a startling statement, but with the whole facts before you, it will become extremely simple. I have, on a previous occasion, shown that the electrical resistance of selenium is very much reduced immediately it is exposed either to solar or artificial light; consequently if a bar of selenium, excluded from the light, form part of a circuit in which are included a battery, a telephone, an electrical bell, and a galvanometer, nothing will be heard until the light be allowed to fall upon the selenium, which is done simply by raising the lid of the box in which the selenium is placed, when immediately sound is heard in the telephone, the bell rings, and the needle of the galvanometer moves, simply because the resistance of the circuit is reduced, and consequently the electro-motive force increased. Now, when I read that Professor Hughes had discovered that bodies were susceptible to sound as selenium to light, I removed the selenium from the circuit, and substituted every substance I could think of in its place, and used every conceivable means to produce sound, but without effect. But if, in a metallic circuit, be placed either a loose contact, or a sensitive commutator, then one can produce all the phenomena claimed for the microphone. I have obtained very satisfactory results from three very fine "rat-tail" files placed in the circuit, similar to the letter H, one end of each of the side files being fixed, and the other file simply lying across them; the longer the side files, and the nearer the cross one is placed to the unsupported ends of the other two, the better; if the cross file be replaced by loose threads of metallized silk, and a spirit lamp be placed beneath the same, so as to create a draught, then is heard in the

telephone a noise similar to the sound of the burning wick of the lamp, especially when first lighted. What Professor Hughes has discovered is, that by allowing the breath or other motive power to affect a sensitive loose contact or commutator, contacts of varying duration are made, which are reproduced in corresponding sounds on that marvellous instrument, the telephone. This is an important discovery, and Professor Hughes has my hearty congratulations.

Mr. Latimer Clark: I did not intend to make any observations, and I feel almost out of place, after the eloquent addresses we have heard, in going back to the ordinary technical view of the subject; but I would just remark that Mr. Preece has, I think, omitted to mention one of the experiments of Professor Hughes. The little glass cylinder you see here (*exhibiting*), with small segments of willow-wood carbon dipped in mercury, is extremely sensible to heat; so much so, that the approach of the hand or other warm body causes very great variation in the resistance of the circuit, and also causes a noise in the telephone. So does a slight alteration of the pressure on the end. If you press on the end of the tube, you cause a noise in the telephone, and produce great deflection of the needle of the galvanometer. You might make a sensitive relay by causing a needle or an electro-magnet to slightly compress the segments in this tube, which would doubtless be more sensitive to delicate currents than any relay we have at present. I therefore throw out the suggestion, in order to make it public. I also think a very excellent Morse sounder may be made from the microphone, by causing a continual sound to be produced in the telephone, and it is obvious that one source of movement would cause any number of instruments in an office to produce continuous sounds, the signals would be received on a relay, and would come out, not as dots, but as dots and prolonged dashes, which could be more accurately and easily read than the ordinary sound signals.

Lord Lindsay, M. P., F. R. S.: I will only mention one experiment which struck me as being interesting. I constructed one of Professor Hughes's little instruments from a description which I read of it, and having stretched a piece of parchment over a circular frame so as to form a vibrating membrane, I attached to its centre a piece of carbon, which was connected in circuit with a battery by means of a fine copper wire. Against this piece of carbon I placed

a second similar piece, so arranged that I could increase or diminish its pressure upon the first piece by means of an adjusting screw, and to this piece was also attached a copper wire, by which it could be placed in circuit with a battery and telephone, and with the other piece of carbon. Under the influence of sonorous vibrations the membrane vibrated, and in doing so produced a variation in the pressure, and consequently in the electrical contact between the pieces of carbon, reproducing the original sounds in the distant telephone. On one occasion I placed the apparatus on the sounding board of a pianoforte upon which my little girl was practising (she was playing scales), and I noticed a very remarkable effect. Whenever one particular note was struck, a harsh loud sound was heard in the distant telephone, although all other notes were clearly transmitted and reproduced. On examination, I found that the note which produced this curious effect was that whose period of vibration corresponded with that of the membrane, and in the sound produced could be heard the fundamental note and overtones, as well as the octaves and other sympathetic notes sounded by the strings of the pianoforte.

Prof. Graham Bell: No one can more heartily congratulate Professor Hughes upon his great discovery than I do. I think all those who investigate telephonic effects will realize that we have touched upon the threshold of a new science, and that we have discoveries yet in store for us. I must confess that the explanation of the action of the microphone afforded by Mr. Preece and Mr. Willoughby Smith are to my mind not perfectly satisfactory. There are certain points in the telephone itself that may lead us to the true solution of this problem. If you fix your attention upon the first diagram shown by Mr. Preece, you have a constant source of electricity (the battery), a telephone, and this curious instrument. Now, the laws of audibility of the electric current by the telephone are analogous to the laws of induction. No sound is audible so long as your current is of uniform intensity. But the moment you change its intensity, you have a sound from the telephone. Conversely, when you have a sound from a telephone the intensity of the current passing through it has been changed; and the loudness of the sound is an index of the amount of change. Now, unless the microphone were itself a source of electricity, it is evident that the only way in which it can change the current is by varying the resistance of the

circuit. So far we may be perfectly certain that the action of this instrument depends upon the variation of the resistance; and the only question as to how this variation of resistance can be accomplished, by the influence of such feeble sounds as those produced by the escapement of a watch, or the footsteps of a fly. As the sounds produced from the telephone are quite loud, the current must change very greatly in intensity, and the resistance of the microphone must vary in a most extraordinary manner, probably being at its maximum many times the resistance of the rest of the circuit, and at its minimum but a fraction of it. Mr. Preece seems to consider that the molecules of the substance composing the microphone change their shapes when subjected to compression by a variable force; and he has figured to us his conception of the alternate contraction and expansion of a chain of molecules under the influence of sound. Mr. Willoughby Smith, on the other hand, attributes the effects produced by the microphone to imperfect contact. He supposes the carbon points to rattle against one another under the influence of a sound, and he seems thus to regard the microphone as a delicate form of interrupter. I am more inclined to accept Mr. Willoughby Smith's explanation than that given us by Mr. Preece; but the reproduction of articulate speech negatives the assumption that the microphone acts as interrupter. The possibility of producing electrically any given quality of sound depends upon the possibility of producing a current of electricity, the intensity of which varies in a manner proportional to the varying velocity of a particle of air during the production of that sound. Hence, however much the points in contact may rattle together, the circuit must not be broken or the effect of quality will be lost and a mere noise be produced instead. If I might offer a suggestion, I think it probable that there is a variation in the amount of contact. Let us suppose an enormous number of particles to be in contact (each singly offering a high resistance to the passage of a current, but conjointly offering very slight resistance), then when the microphone rattles under the influences of a sound, a larger or smaller number of particles come into contact, and the resistance of the microphone changes without absolute break of circuit. Still we must not forget that at each increase of resistance, heat must be produced at the points of contact, and it is probable, nay, extremely likely, that heat has a great deal to

do with the results obtained. I was experimenting with a microphone the other day, and it kept on vibrating on its own account for nearly two minutes. A clear musical tone was emitted by the telephone in circuit with it. The microphone always exhibits a tendency towards vibration on its own account, when it is adjusted most delicately. The instrument, as I constructed it, consisted of a rod of charcoal placed horizontally, with its ends resting upon two other rods of charcoal. This arrangement, when shown to Professor Dewar, at once suggested to his mind Trevelyan's bars I think it not at all unlikely that the microphone is in reality a species of Trevelyan's rocker, and that it may thus be in a condition to be affected by feeble sounds. It is quite conceivable that sounds too weak by themselves to throw the mass of the microphone into sensible vibration, may yet be sufficiently strong to start and control the vibrations due to heat, or at least it is conceivable that heat may assist the action of the sound. For instance, suppose the charcoals rattling together under the influence of a sound.

Now, as the charcoals separate, the resistance of the microphone increases, the points of contact become heated, and the expansion due to this cause occasions a greater separation than would otherwise take place. Thus heat may co-operate with a feeble sound to produce a greater amplitude of vibration at the points of contact than would be produced by the sound alone. Those who are interested in this subject would do well to read Professor Page's paper upon "The Vibration of Trevelyan's Bars by the Galvanic Current." The microphone recalls vividly to my mind some of the illustrations in this paper. Whatever may be the true explanation of the effects produced by the microphone, there is evidently a vast field open before us for inquiry. I will not take up your time with any further remarks, but will merely again offer my congratulations to Professor Hughes upon his discovery.

PROF. HUGHES: It seems that the description of the microphone is not well understood. I can excuse that, because it is as much as I can do to understand it myself; but as far as my experiments have gone, they show that the effects produced are the result of the increase and diminution of the resistance. Mr. Willoughby Smith designated it a commutator, and attributes the effects to contact.

That is quite right, only it is not from the point from which I view it, and that is the way in which the effects differ.

If we take a board like this (*illustrating*), and give it a blow here, that nail will jump up from the transmission of force. The same thing takes place in acoustic properties. A blow is simply rapid pressure, as distinguished from hydraulic pressure; the difference between a blow and hydraulic pressure is one of rapidity. If you take a piece of glass and put sand on it, and strike the glass, the sand will jump away and form figures. So it is here. (*Professor Hughes illustrated his views by means of diagrams on the board, showing the curves of articulated sounds, both in speaking and singing, etc.*)

THE PRESIDENT: As time is advancing, and as Mr. Preece, I believe, has some further experiments to exhibit, at the close of the meeting, I will make a few observations only on the very interesting matter which has been brought before us. The discussion that has taken place is remarkable for the excellent temper which has been shown between two great rival discoverers. I think all of us must have been pleased to have seen how these two gentlemen, Professor Bell and Professor Hughes, have described and brought before us their particular views regarding certain actions in the two instruments, the telephone and microphone, which, when we come to compare them, will be found to have many points of analogy, and though essentially different in detail, tend towards the accomplishment of the same important end. Mr. Preece and Professor Bell differ with regard to the action which takes place in the microphone; and Professor Hughes favors naturally the views which Mr. Preece had expressed; but I think there is probably not so much difference between these two views. It is quite evident that the action of the microphone is due to variation in electrical resistance produced by vibrations in an imperfect conductor, such as carbon, or an aggregate of divided pieces of metal, and the question for consideration is how this variation in resistance is effected. When two pieces of carbon are pressing one upon the other, and vibration is imparted to one of them, it is easily conceived that in consequence of this vibration the pressure between the adjoining points of the carbon will be modified, and in consequence of such variation in pressure, the electric cond[illegible]

according to Professor Hughes's application, the cause of variations in the electrical resistance must be looked for in the lateral increase of points of contact.

We have another discoverer who has already thrown light upon this subject, viz., Mr Edison of New York, the well-known discoverer of the phonograph, who, in constructing a form of telephone of his own, introduced carbon contact, which gave him resistances variable with the amount of physical pressure he brought to bear upon the carbon; and I must say that this question of varied resistance due to vibration will probably resolve itself simply into a question of pressure between particles of matter which are conducting in themselves, but which are held so lightly in contact that pressure is needed in order to establish conductive continuity.

I should have liked that something more had been said of this discovery of the microphone, with reference to its two elder sisters, the telephone and the phonograph, being of opinion that the three are only separate steps in the achievement of an advance in physical science which bids fair to be considered hereafter as one of great moment, not only as regards telegraphy, but as a means also of affording a more perfect insight into the nature of molecular action. We have heard from Mr. Willoughby Smith, that in substituting crystalline selenium for carbon in the microphone, a ray of light produces an effect analogous to mechanical vibration, and announces itself in a report comparable to a clap of thunder; and I can quite follow him in his arguments with respect to the matter.

His Grace the Duke of Argyll alluded to the application of this discovery to physiological research, and I could have wished that some of our learned physicians had taken up this point in the discussion, because I believe myself that the influence of these discoveries upon physiological research will be very great indeed. One thing has occurred to me in considering these matters, which I will take the liberty of mentioning. We have the remarkable effect of the phonograph producing a record of sounds simply from the indents given to a slip of tin-foil, which record can be reproduced at any time. This strikes me as being an exceedingly analogous case to the impress produced upon the brain by what we hear and see. An impress is produced, which for the moment seems lost, but which, in a vig-

memory is not conceivable on any other hypothesis but that of a mechanical record being left on the brain, and stored up for perhaps half a century, to be restored in the succession in which it has been laid down; otherwise, how could the human mind reproduce impressions imparted years ago at will, or how could they be involuntarily revealed in our dreams? The discoveries which are now brought before us will undoubtedly serve to increase our stock of knowledge on physiological and metaphysical as well as physical subjects, regarding molecular action, of which we have hitherto had but very imperfect indications; and I think we cannot be too thankful to those gentlemen who have enabled us to discuss them as we have done, and I will therefore move that a hearty vote of thanks be given to Mr. William Preece for his communication. I think our thanks are also due to the two discoverers who are here to-night, and have given us the benefit of their views. I therefore propose that we also return our thanks to Professor Hughes and Professor Graham Bell.

The votes of thanks were unanimously accorded.

Mr W. H. Preece: My remarks will be very few. As I said when I spoke on the theory of the thing, I had not time to enter into it. In point of fact, there is no real difference between the views of Mr. Willoughby Smith, Professor Graham Bell and my own. The only difference is difference of language. Most differences in scientific controversies are attributable to difference of language. Whether variation of current is due to difference of contact or difference of pressure, matters very little, provided we use contact and pressure to imply the same thing. That which I call pressure, others call contact; and that which Mr. Willoughby Smith calls contact, I call pressure. It has afforded great pleasure to me to bring this matter before you. I have had, during the last twelve months, the pleasure of introducing before you the telephone, the phonograph, and now the microphone; and I hope next year, when we meet again, it will still be my pleasure to bring forward other new inventions and discoveries. I was anxious that Professor Hughes should have brought this subject before you himself; but, if I had not undertaken to do so, you would not have had it. Beyond assisting Professor Bell, Mr. Edison and Professor Hughes in any way I could, I can claim no merit of my own, either in respect to the telephone, the phonograph or the microphone.

The meeting then adjourned to the 13th of November.

THOMSON & HOUSTON MICROPHONE RELAY.

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THE MICROPHONE RELAY.

BY PROFS. EDWIN J. HOUSTON AND ELIHU THOMSON, OF THE PHILADELPHIA CENTRAL HIGH SCHOOL.

Immediately after the announcement by Prof. Bell of his remarkable invention of the articulating telephone, we proposed for ourselves the task of relaying this instrument. Quite a number of different arrangements were tried, but, owing to the exceedingly feeble movements of the diaphragm of the receiving telephone, none of them were very successful. The discovery by Prof. Hughes, however, of the inexpressibly delicate microphone, happily afforded us the means of at last solving the problem at which we had been so long engaged.

In our application of the microphone for the relaying of the telephone, we attach a miniature microphone to the plate of the receiving telephone. The microphone so attached consists essentially of three small pieces of carbon, each being about three eights of an inch in length. These pieces are arranged exactly as in the manner described by Prof. Hughes, viz., one of the pieces of carbon, which is sharpened at both ends, rests vertically in small cavities near the ends of the two other pieces, as shown in Fig. 1. The two carbon supports for the third piece are cemented at their ends directly to the plate of the telephone.

The microphone so constructed is placed in the new circuit in which it is desired to repeat the message originally transmitted. The method of its operation is evident. The slight movements of the diaphragm of the receiving telephone, which are, in fact, so slight as to render them almost impossible of detection by mechanical means, are nevertheless at once recognized by the marvellously sensitive microphone, and are repeated in the new circuit as variations in the intensity of the electrical current traversing it. The message so relayed or repeated, for it is evident that the instrument can be used either as a relayer or a repeater, may be either received at once by a

telephone placed in said circuit, or may be again repeated in a new circuit. By this means we believe that the distance to which a telephone message can be transmitted will be very greatly increased.

Owing to the extreme sensitiveness of the microphone, it will be necessary, in the practical application of this instrument as a relay, to carefully shield it from all extraneous sounds, which, weak though they may be, are nevertheless very loud when compared with those which would be produced by the feeble movements of the plate of the receiving telephone. This may be obtained in practice in several ways, as, for example, by placing the microphone relay in a box with double or treble hollow walls lined with cotton, wool, or some other non-homogeneous material, or by sinking the instrument in a pit under ground. We have found but little difficulty, however, in the trial of our instrument over a city line of some three miles in length, of obtaining the quiet necessary for the working of the instrument, although the latter was placed in a large room in the second story of a building facing a public thoroughfare, and the time of trial was shortly after midday.

The microphone, when properly constructed, has its greater sensitiveness when the piece of carbon, pointed at both ends, rests in a nearly vertical position. Its electrical resistance is then at its maximum. In this position the upright carbon is resting on its extreme ends, and the cross section of contact a minimum. So placed, the slightest acoustic movement brings portions of the conical surfaces of the upright pieces against the edges of the cavities, and thereby diminishes the resistance by increasing the area of the surfaces in contact. If now it be desired to diminish the sensitiveness of the instrument, it is only necessary that it be so placed that the upright carbon be no longer supported vertically, but be slightly inclined. In this position more force is required to move the upright piece, and so cause it to vary the electrical resistance. In all the microphones that we have experimented with when the upright piece was held nearly vertically, whispers or other faint sounds were distinctly transmitted, but the voice of a person standing a few feet from the instrument, and speaking as in ordinary conversation, caused such a rattling of the receiving instrument as either to render the sound unintelligible or greatly confused. In all such cases a certain in-

clination could be obtained, varying slightly in each instrument, at which the rattling of the instrument entirely disappeared, and the sound was distinctly and loudly transmitted.

When the microphone relay is placed in a circuit whose resistance is considerable, as, for example, at the end of a distant station, we increase the sensitiveness of the instrument by attaching a number of minute microphones to the receiving diaphragm, as shown in the figures. These may be connected in series, as in Fig. 3, or in multiple arc, as in Fig. 2.

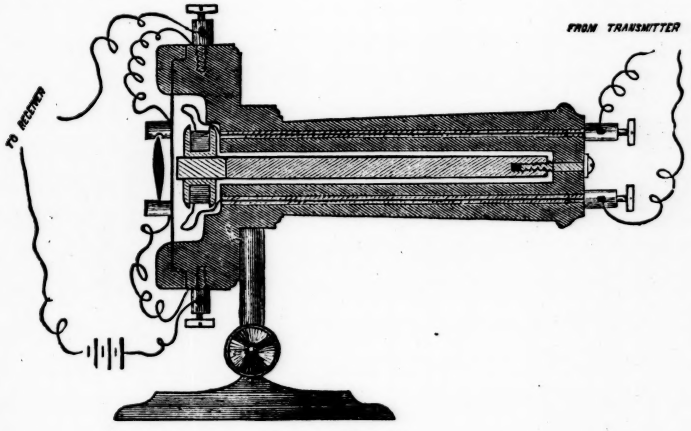

FIG. 1.

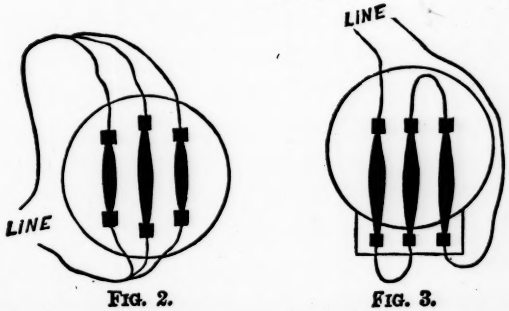

FIG. 2. FIG. 3.

Since the variation in the electrical resistance of the microphone depends mainly on the upper contact of the loose piece with its support, an increased delicacy may be obtained by attaching this support directly to the middle of the diaphragm of the receiving

instrument, while the lower support need not necessarily be attached to the diaphragm.

We have measured the resistance of a microphone, in which the movable piece was composed of a piece of carbon about one and a quarter inches long and a quarter of an inch square, and find that when placed in an upright position it has a resistance of about fifty ohms, varying, however, in a marked manner, with any sound. The same instrument, when turned at an angle of about 40° from the vertical, was found to have its resistance diminished to about twenty-five ohms.

It may be mentioned, as an interesting fact in regard to the micro phone, that when the upright piece is placed in the position of its greatest sensitiveness, and a moderately loud sound is made near it, although such sound is only transmitted as a confused rattling, yet its resonance can, in most cases, be distinctly heard. This is probably the cause of the peculiar ringing sound heard when the microphone transmits mere noises, such as those produced by a person walking.

DEPARTMENT OF THE INTERIOR.

UNITED STATES PATENT OFFICE.

To all persons to whom these Presents shall come, Greeting:

This is to certify that the annexed is a translation, by the Official Translator, from the bound volumes of this office, of the specification, in the matter of the German Letters Patent, granted Robert Lüdtge, January 12th, 1878, Number 4,000, for Improvement in Transmitter and Relay for Electric Telephones, together with a tracing of the drawing forming part of said patent.

In testimony whereof I, M. V. Montgomery, Commissioner of Patents, have caused the Seal of the Patent Office to be affixed this 7th day of October, in the year of our Lord one thousand eight hundred and eighty-six, and of the Independence of the United States the one hundred and eleventh.

[SEAL] M. V. MONTGOMERY,

Commissioner.

GERMAN PATENT 4,000. ROBERT LÜDTGE IN BERLIN.

TRANSMITTER AND RELAY FOR ELECTRIC TELEPHONES.

PATENTED IN GERMANY, 12 JANUARY, 1878.

The principle and the construction of the Bell Telephone entail, in so far as it is used for receiver and transmitter, several inconveniences that cannot be removed without a change of principle, but which interfere with its employment for long distances as well as for household uses. The fact that the instrument is constructed only for induction currents and is very sensitive to these same, alone introduces the annoying adjunct, that all other disturbing operations of induction, such as working on collateral lines, make themselves very perceptible. The fact that these induction currents are engendered by the vibrations of the air produced by our mouths alone without the assistance of any ulterior source of power, make them seem too weak for intercourse over large lines, and for domestic use not sufficient to compete with the disturbing noises in the neighborhood.

Considerable progress is made towards meeting these objections by using for telephoning not induction, but battery currents, that offer the further advantage, that, as a new additional source of power, they allow the operation to be intensified. In this connection several experiments have already been made and their results published.

Before all such, must be mentioned the telephone invented by Reis in 1863, but the trouble with that is, that in response to the vibrations of sound, it only just opens or closes the battery current. The greater or less intensity or amplitude of the sound waves can, therefore, not express itself in a greater or less intensity of the battery current. The more delicate relations of vibrations which is the first thing to characterize a letter or a word find no expression, hence disappear in the final operation which, in consequence, consists almost solely of the repetition of the rhythm of the fundamental tone.

Furthermore, there belongs in this class the telephone of Edison, in New York, which uses the vibrations of a metal plate that is talked at, more or less to compress an appropriately applied piece of graphite introduced into the circuit of a battery, and inasmuch as the resistance of the graphite is influenced by the pressure so the intensity of the current is changed by the vibrations of the plate. The present invention is founded essentially on the following discovery: —

If a point of interruption is introduced in the circuit of the battery, say by simply cutting the conducting wire, and laying the two cut surfaces against each other, a passage resistance will arise at the point of the cut that will be smaller in proportion as the two cut surfaces press more strongly against one another. This fact is easily verified by the aid of a sufficiently sensitive galvanometer; it can also be verified by a Bell Telephone introduced into the circuit, as it can then be distinctly heard how the current is restored when the two cut surfaces are brought together again, and then how it is changed in intensity according to the force with which the surfaces are pressed together.

Now, if the one cut surface be so constructed as to be set in vibra-

tion by speaking or other noise, it will be made to press upon the other cut surface in contact with it variously according to the intensity and form of the single vibrations. The passage resistance at this point will be exactly influenced in magnitude by the intensity, form and number of sound vibrations of the sounding surface and therewith determines also the intensity of the battery current already existing in the circuit. In other words, each sound vibration which the sounding surface performs, causes a simultaneous increase of intensity of the battery current exactly corresponding to the amplitude of the sound vibration, and a Bell Telephone introduced into the circuit will translate this increase of intensity back again into the corresponding operation of sound. As this process is valid for every vibration, the Bell Telephone acting as receiver will allow all the vibrations to be heard that are produced by the one cut surface at the point of interruption acting as a transmitter, and that, too, with all the refinements, as no closing and opening of the current takes place, but merely an increase or decrease of intensity according to the force of the pressure with which the two surfaces touch, and which in this case is altered only by the vibrations executed by one surface against the other when giving forth sound or else being talked at.

From what has gone before it is clear what principle it is that serves as a foundation for the present invention. Now follows the constructive application of this principle : —

The construction finds as its most essential problem the manner in which the two ends of the point of interruption, hitherto designated as "cut surfaces" shall be shaped, in view of the object to be attained. These two ends must remain uninterruptedly in contact, so that the circuit shall always remain closed, but the intimacy of their contact must be so slight that at the point of interruption a perceptible passage resistance is offered to the electricity ; that the intimacy of the contact and with it the passage resistance shall vary as soon as one *or** both of the two ends is set into sound vibration.

In this connection it must be observed that the contact for this

*Misprint in the German "ober" for "oder."

reason must not be too intimate, that the sound vibrations of the one end must always be perceptible to say the least.

To solve this difficulty various constructions have been applied each especially suited for some peculiar collateral purpose. The following parts are common to all the different constructions : —

1. A battery for developing electricity. The strength of the same depends on the length of the circuit, intensity of operation to be produced, etc.

2. A conductor of ordinary electric conducting wire.

3. A telephone of Bell construction introduced into the circuit at the receiving station to receive the despatches.

For the transmitter introduced into the circuit at the transmitter station and forming the object of this invention, the following constructions have given the best results : —

The first construction is shown by Fig. 1, of the accompanying drawing. Against a round, smooth metallic plate *a* (sheet iron, sheet zinc, thin silvered glass, etc.), fastened in a wooden ring from 2 to 10 cm. in diameter and not thicker than 1 mm. set in connection with one pole of the battery by the wire *b* or else by the ground wire, there is pressed a metallic pin *c* connected with the other pole of the battery (adjusted) by means of a micrometer stand and screw *d*, so that it touches the plate gently and closes the circuit by means of the conducting wire *e*. Now if speech or song is directed against the plate *a*, then the intimacy of the contact between plate and pin will be varied and the required operation produced. The micrometer screw must be cut very fine to admit of the most advantageous adjustment of the pin, and as the apparatus is sensitive to the slightest jar, it will be advisable to set it up on an insulating column. Unavoidable changes of temperature occasion a frequent readjustment. Due consideration being had for these inconveniences in accordance with the exigencies of the case, this construction will commend itself by its very great sensitiveness and its very favorable intensity at the receiver station. Furthermore, in Fig. 1, *f* is the wooden shell, (fastening), *g* the speaking trumpet, *h* the battery, *i* the ground plate, *k* an insulating layer for the platinum point, *l* clamp screws,

m the spindle of the micrometer screw, *n* the receiver. The pin *c* can also be replaced by a second plate *b* as shown in Fig. 2. In this case the micrometer screw is replaced by a screw-threaded brass ring *l*, to adjust the relative positions of the plates *a* and *b*. In this construction it is indifferent which of the plates is spoken at. It is better to vault one of the two plates, as shown in Fig. 2.

Furthermore, in the same figure, *h* is the wooden ring for enclosing the whole, *p* the wooden ring for holding the plate *b* fast, *l* and *q* brass rings screw-threaded, *m* clamp-screws for the conductors *r* and *s*. A second method of securing the proper contact of the plate *a*, with the pin *c*, or the other plate, is to allow the pin or the plate to lie upon the plate *a*, with its own weight.

This construction is shown in Fig. 3 for plate and pin, and in Fig. 4 for two plates. The pin *c* stands vertical, moving easily in a metal tube *b*, but always in conducting contact. It is gently pressed by its own weight upon the plate *a*. The intimacy of this contact is regulated first by the weight of the pin, then by the inclination given to the whole apparatus. The meaning of the remaining letters in Fig. 3 is as follows: *a* arm for the contact pin, *r* oscillating plate, *f* wooden fastening (shell), *w* clamp screws, *l* conducting wires, E receiving station, B battery. In using the plate, Fig. 4, the means of adjustment remain the same, the plates *a* and *b* are introduced into the circuit by thin wires *r* and *s*.

A third method of adjusting the contact both for plate and pin and for two plates is shown in Fig. 3. In other respects the construction is like the preceding, only that underneath the plate a magnet or electro-magnet *m*, is applied whose attraction for the iron pin or plate above the oscillating plate serves to regulate the intimacy of contact. A fourth method shown in Fig. 5 is by adjusting and fastening the two contact plates by pads of wadding, a construction distinguished for its simplicity and handiness if not for great (excellence of) operation.

In general the constructions with two plates are more durable and simpler to manipulate, and work much neater and cleaner. But the pin and plate construction works with greater sensitiveness and intensity. It will be clear from what has gone before, that all constructions mentioned will fit for the use of the transmitter as a relay,

as Fig. 6 shows. In this case the plate *a* is identical with the iron plate of the Bell Telephone, only it is set in vibration now, not directly by the voice but by inductive and magnetic forces operating below it called into action at the transmitter, and then propagates the vibrations received to the receiving station as a transmitting apparatus would do.

Claim. The construction of a telephone transmitter which operates by means of the variations produced by sound vibrations in the intimacy of contact of two or more solid electric conductors, is driven by battery currents and can also be used as a relay in telephone establishments.

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ROBERT LUDTGE IN BERLIN.

Aufgabe-Apparate und Relais für elektrische Fernsprech-Einrichtungen.

Fig. 3.

Fig. 1.

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ROBERT LUDTGE IN BERLIN.

Aufgabe-Apparate und Relais für elektrische Fernsprech-Einrichtungen.

Fig. 1.

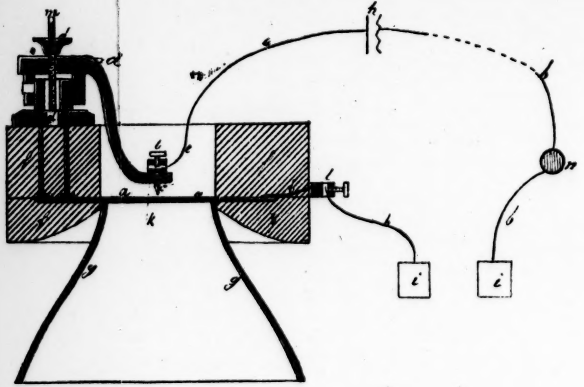


Fig. 3.

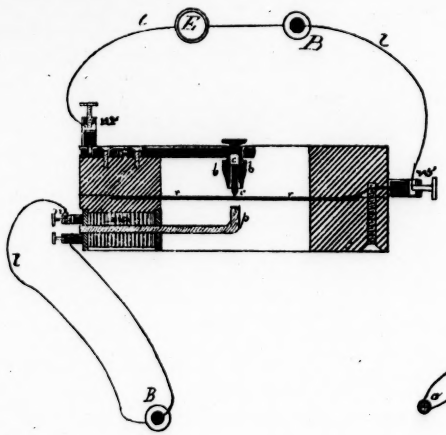


Fig. 6.

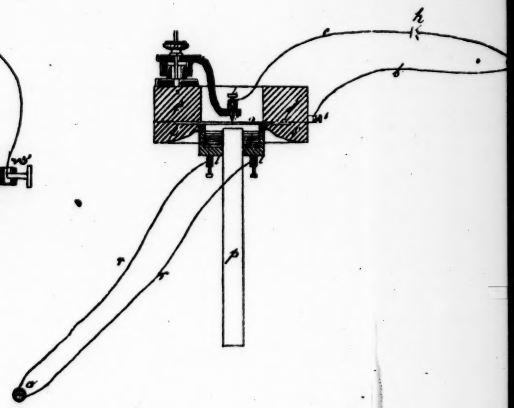


Fig. 2.

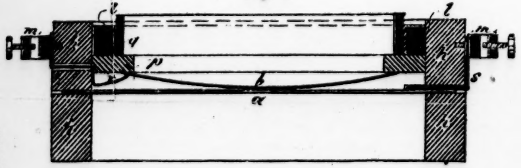


Fig. 4.

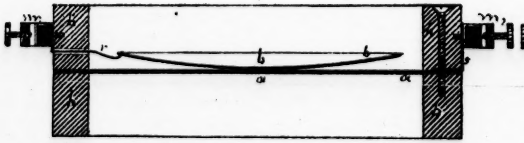
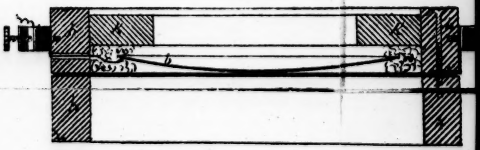


Fig. 5.



PHOTOGR. DRUCK DER KÖNIGL. PREUSS. STAATSDRUCKEREI.

Zu der Patentsch

№ 4000

CERTIFIED COPY AFFIDAVIT OF GEORGE GIFFORD IN THE GHEGAN CASE.

United States Circuit Court,

DISTRICT OF NEW JERSEY.

IN EQUITY.

AMERICAN BELL TELEPHONE COMPANY

v.

JOHN J. GHEGAN ET AL.

AFFIDAVIT OF GEORGE GIFFORD.

STATE OF NEW YORK,
CITY AND COUNTY OF NEW YORK, ss.

George Gifford, being duly sworn, deposes and says: I am a counsellor at law, practising in the city of New York. In the years 1878, 1879 I was one of the counsel of the Western Union Telegraph Company.

At that time the Gold and Stock Telegraph Company, a company connected with the Western Union Telegraph Company, had manufactured and were controlling the use of many thousands of telephones, and had established telephone exchanges, auxiliary to their telegraph business, in the city of New York and elsewhere. The telephones controlled by this company were composed of a receiver, now generally known as the "Magneto Receiver," and understood to be substantially a thing described in Bell's patent; but they were of a form which was claimed had been constructed by Phelps and Gray. The transmitters were carbon microphone transmitters, constructed under the plans of Edison and Phelps, and were in controversy in applications for patents by Edison and Phelps, and contained the

induction coil covered by the Page patent, also owned or controlled by the Western Union Telegraph Company.

A bill in equity was brought against a defendant, Dowd, who was understood to be one of the agents of these companies, and the suit was defended by the Western Union Telegraph Company. An answer was filed, setting up a great variety of defences, all of which will appear by reference to the record itself. Among other defences, the European publications relating to Reis's invention were relied upon, and it was alleged that Bell's telephone, as described in his patent, was not capable of talking.

Elisha Gray was also set up as a prior inventor, and the inventions of Edison and Dolbear were pleaded.

A very vigorous defence was made by the Western Union Company, and testimony of great length and at great expense was taken in support of the answer. After the testimony was closed, or substantially closed, on both sides, I was convinced that Bell was the first inventor of the telephone, and that the defendant, Dowd, had infringed said Bell's patent by the use of telephones in which carbon transmitters and microphones were elements, and that none of the defences which had been set up could prevail against him; and I advised the Western Union Company to that effect, and that the best policy for them was to make some settlement with the complainants.

For the purpose of effecting such a settlement, the position of the Western Union Telegraph Company was very strong. They owned or controlled what is known as the Page patent, and which covered the "induction coil" used in the transmitters of the telephones, and was of great importance to them. They also owned or controlled two patents of Gray for harmonic telegraphs, which it was contended would be infringed by the use of the Bell telephone; and they controlled applications for patents by Gray for a receiver used in a telephone, and by Edison for carbon transmitters and microphones, which it was claimed and expected would be granted in the Patent Office over Blake, whose transmitter the Bell Telephone Company claimed to control and had in use. The situation then was that while I believe that Bell was the inventor of the telephone described and claimed in his patent, and that his patent covered the various

forms of telephones controlled by the Western Union Telegraph Company, in which carbon transmitters and microphones are elements, yet the Western Union Company controlled patents and inventions which it was claimed might cover all known forms of telephones.

Under my advice, a negotiation was opened with the complainants on the basis of the claims which the Western Union Telegraph Company made, that the telephone used by the complainants was an infringement of the patents and applications for patents owned or controlled by the Western Union Telegraph Company. I met Mr. Chauncey Smith, counsel for the Bell Telephone Company, by arrangement, at the White Mountains, where we remained for a week in negotiation. I opened the negotiation on my part by admitting that Bell's patent was valid, and that the defendant infringed it; and those questions formed no part of any discussion between us; but I claimed, on the part of the Western Union Company, in view of their patents, that all the patents should be put together, and that they should have one-half interest in the joint property. This claim was refused by Mr. Smith, and the negotiation failed at the White Mountains. Upon our return to New York, however, the principals themselves took it up, and the negotiation resulted in the surrender by the Western Union Company to the Bell Telephone Company of certain telephones, lines and exchanges, and in their giving to the Bell Telephone Company an exclusive license under all the patents which they claimed were infringed by the telephones.

In exchange for these licenses the Western Union Company got a small interest, much less than I claimed for them in my conference with Mr. Smith, in the results of the combined patents, and the entire business was left in the hands of the Bell Telephone Company.

The negotiations on the part of the Western Union Telegraph Company were conducted by a committee of three, composed of Dr. Green, Gen. Stager and George B. Prescott, who at that time was the electrician of the Western Union Telegraph Company and vice-president of the Gold and Stock Telegraph Company, and the author of a book on the "Speaking Telephone." The negotiations lasted for some months, and every step was vigorously contested until all

the points were agreed upon, and the settlement met my approbation as counsel. The proceeding was adversary from beginning to end; but, in view of the facts as they appear in evidence, it was conceded in behalf of the Western Union Company in the beginning of the negotiation that Bell was the first inventor of the telephone. If the Western Union Company had prevailed in their interferences, the Bell Telephone Company could not have used in their business the Blake transmitter, or any other form of carbon transmitter, and, inasmuch as the carbon transmitters with the induction coil are valuable improvements in the telephone, the Bell Telephone Company would have been compelled to purchase them at the Western Union Company's price.

This settlement never would have been advised by me if I had not believed, upon the record, or through facts which I could ascertain, that the Bell patent was valid, and that all microphones and carbon transmitters, as far as I know or could ascertain, infringed it.

GEO. GIFFORD.

Subscribed and sworn to before me this 19th Sept. 1882.

[SEAL] W. F. HAPGOOD,
Notary Public,
N. Y. Co. (102).

A true copy.

[SEAL] S. D. OLIPHANT,
Clerk.

NOTES OF EXPERIMENTS IN THE DOLBEAR CASE, RELATING TO THE USE OF REIS TRANSMITTER WITH MODERN MAGNETO RECEIVERS, AND OF REIS RECEIVERS WITH MODERN CARBON MICROPHONE TRANSMITTER.

BOSTON, June 2, 1883.

The experiments took place as follows: —

NOTES OF MR. BARNES, SHORT-HAND WRITER, AT THE TRANSMITTING ROOM.

Transmitting station: Present, Mr. Maynadier, Mr. Storrow, Professor Cross, Mr. Eaton and Mr. Barnes.

At the receiving station: Mr. Buck at the receiver, Mr. Chauncey Smith, Mr. Copeland and Mr. Leighton.

At the transmitting station: Defendants' Exhibit *Reis Transmitter* connected in circuit with one Grenet cell, and a finger key in the circuit which opens the circuit when not in use.

In the receiving room connected with this is the *magneto receiver No.* 9, Mr. Buck listening at it; also, between the two rooms, an independent circuit used as a telltale line, with a magneto telephone at each end, Mr. Smith attending at the end in the receiving room, and Mr. Storrow in the transmitting room.

[Mr. STORROW (through telltale line): Hullo! hullo! are you ready?]

Mr. EATON (speaking against the top of the Reis transmitter and not into the mouthpiece): Hullo! Mr. Buck. Do you get this all right? Mr. Buck, are you all right, Mr. Buck?

[Mr. STORROW (through telltale line): Hullo! are you ready? Hullo! hullo! are you ready and listening?]

Mr. EATON (speaking as before and about a foot away from the transmitter): Hullo! Mr. Buck. One, two, three, four, five. Do you get this all right? [Time 10.52.] A gentleman here says not to go so quick. How do you like it? One, two, three, four, five, six, seven, eight, nine, ten. Mr. Buck, I don't know whether I have got this arranged just right or not, because I can't get any word from you, but I guess you will get some of it all right. How do you like that, Mr. Buck? Boston, Charlestown, twenty-five, eighty-four, one hundred and one, two. Get any of those figures? Hullo, Mr. Buck, did you get any of that? One, two, three, four, five, six, esven, eight, nine, ten. How is that, all right?

[Mr. STORROW (telltale line): Hullo, what is it? Hullo there, what is it?]

Mr. EATON: Hullo, what is it?

[Mr. STORROW (telltale line): Hullo, Mr. Smith, Hullo, hullo.]

Mr. EATON: Hullo, Mr. Buck. Mr. Storrow was hollering to Mr. Smith; didn't any of you get anything there?

[Mr. STORROW (telltale line): Hullo, are you ready, listening? Now we will go ahead.]

Mr. EATON: Mr. Storrow tells me to go ahead, Mr. Buck. Are you listening there? One, two, three, four, five. How do you get that, all right? Am I about the right distance away? Would you rather have me speak down in here than up on top? How do you get this? (This last sentence spoken into the mouthpiece.) Hullo, I understand you want it a little lower. How do you get this, Mr. Buck, all right? Boston, Charlestown, Somerville, seventy five, eight hundred and twenty, three, sixteen, eighty-five, twenty-four. Get that all right? The defeat which the government suffered in the division on the affirmation bill has set people thinking seriously about their future and that of the present Parliament. It is the first heavy check they have encountered, and our experience is that a ministry which has once been beaten in a pitched battle, seldom recovers its strength, and never its prestige. Had this battle been one of a distinctly party character, the ministry must, of course, have resigned. How is that, all right, Mr. Buck? But the bill they were beaten on was no part of their political programme. They did not take the matter up because they regarded it as one of political consequence, but merely in order to extricate the House of Commons and constituency of Northampton from a dead lock which was disquieting to both Parliament and the country, as they contended that the House of Commons had erred in refusing to permit Mr. Bradlaugh to take the oath after his re-election from Northampton. They might, perhaps, have left it to bear or settle for itself the consequences of that error, but there is a general feeling in England that when any screw gets loose, it is the business of the executive to put it into its place again, and the fact that the question of Mr. Bradlaugh's admission remained open was damaging to the ministry in both directions. How is that, all right?

[Time 10.58.]

[Mr. STORROW (telltale line): Hullo, hullo. Are you ready? About one minute. Are you ready?]

(The speaking so far has been into the top of the instrument, and not into the mouthpiece, and at a distance of from four inches to a foot from the membrane.)

[Mr. MAYNADIER: The trouble is, Mr. Buck says, Mr. Smith wanted him to speak every word he heard and Mr. Buck cannot do that, the way you talk so rapidly, without losing, as you see at once, the greater part of what immediately follows, because while he is speaking, saying what he heard, he loses all that immediately follows. He only knew you were talking about Bradlaugh and the English government; something of that sort.]

Mr. EATON (speaking to top of the instrument. [Time, 11.03.]

Reading): To the editor of the *Nation*, — Sir: In your issue of May 3, "The real Weakness of American Universities," is discussed from the standpoint of professional emolument, without any reference to other, and, as it seems to me, more potent causes for the present low standard of our higher education. The discouraging effects in the end of a poor salary cannot be doubted. Even the most enthusiastic and zealous promoter of any department of science to feel that earnest and continued effort is rewarded through years by only a meagre competence sufficient to keep the wolf from the door.

[Mr. STORROW (telltale line): Hulio. Mr. Buck says you speak too strong. Now, listen. We will go ahead.]

Mr. EATON (reading): Without any possible prospect of being able to provide a small surplus for the contingencies of the future. To see the responsibilities of life grow heavier every day with no hope of meeting them and rising above them by patient, earnest labor, is surely disheartening in the extreme, and yet I apprehend that this is not the worst thing that can happen to a man whose life is devoted to his calling as a professor. This is merely an external source of anxiety, which will cool the ardor and check the enthusiasm.

[Mr. STORROW (telltale line): Hullo! What is it? Yes.]

[Time, 11 07.]

[Mr. STORROW: Well, what is it? Yes, what is it? Yes. *Mr. Buck has taken off No. 9 receiver, and put on No. 10 receiver.*]

[Mr. STORROW: Hullo! Hullo. Are you ready?]

[Time, 11.10.]

Mr. EATON: Hullo, Mr. Buck! One, two, three, four, five, six. seven, eight, nine, ten.

I understand you have got on a different receiver.

Do you get that all right?

"The dissolution of the Reichstag, which at the opening of this session seemed imminent, will not take place, for Bismarck cannot expect by new elections to get a successor which will help him to carry out his policy effectually. Another cause of inactivity and inefficiency in university training in America is connected with the university system itself. Healthy criticism of one another is almost wholly unknown among its professors as a body. It is true we have exceptional cases where judgment is passed upon the labors of a co-worker in a given field, but it is generally done in such a way as to provoke a quarrel in the end, and even this occurs as a rule only between the members of rival institutions, or between men whose positions in life are considered fixed. For the young scholar who is looking for employment, or even after he has received an appointment, the criticisms of the older professors in his own institution or in others is regarded as the effusion of a restive revolutionary spirit which must be squelched forthwith."

[Mr. STORROW: Hullo, what is it? Mr. Buck thinks that will do.]
[Time, 11.13.]
(Mr. Buck says the key makes a disturbing noise. It was suggested it had better be taken out entirely, and he says he prefers to keep it in. Mr. Eaton has opened and closed the key once for each clause or phrase spoken. *The two operators change place, Mr. Eaton goes to listen at the receiving station and Mr. Buck takes his place at the transmitter.*)
[Time 11.17 1-2.]
[Mr. STORROW: Hullo, hullo, hullo! Well.]
Mr. BUCK: Hullo, Mr. Eaton. Do you get that?
Mary and the dog.
The cat caught the rat.
Do you get that?
One, two, three, four, five.
Is that loud enough?
Won't you tell Mr. Smith if you get that all right?
Do I speak strong enough for you?
[Mr. STORROW (telltale line): Hullo, what is it? Speaking a little too loud, you have been.]
Mr. BUCK: I speak a little too loud,do I?
Do you get that better?
One, two, three, four,five.
[Mr. STORROW (telltale line): Hullo, what is it? What is it.]
Mr. BUCK: The dog barks. The dog barks. Do you get that?
Mary and the lamb.
[Mr. STORROW (telltale line): What is it? What is it? Too loud? Now listen.]
Mr. BUCK: One, two, three, four, five, six, seven, eight, nine, ten. How do you get that?
The cat caught the rat.
The rat was caught by the cat.
One, two, three, four, five.
The cat was caught by the rat.
(This last phrase — the repetition — was spoken into the mouthpiece.)
Mr. BUCK: One, two, three, four, five.
The cat caught the rat.
One, two, three, four, five, six, seven, eight, nine, ten.
Mary had a little lamb. How do you get that?
[Time, 11.20.]
(Mr. Buck changes and puts on a fresh cell of the same kind of battery.)
Mr. BUCK: I changed the cell.
One, two, three, four, five.
I changed the cell. Do you get that.
Mary had a little lamb.

Mary and the lamb.
The cat caught the rat.
The dog barks. How do you get that?
One, two, three, four, five.
Mary had a ball.
Mary caught the ball.
John and James. How do you get that?
[Mr. STORROW (telltale line): Well, what is it?]
[Time, 11.22.]
What is it?
Yes. All right, listen.
Mr. BUCK: Are you ready?
To the editor of the *Nation*.
To the editor of the *Nation*.
Then what is to be done?
To what is this due?
The first of these types.
[Mr. STORROW (telltale line): Well.
Talking too loud.]
Mr. BUCK: The first of these types.
[Time, 11.23.]
Then what is to be done?
To what is this due?
[Mr. STORROW (telltale line): Well, what is it?]
Mr. BUCK: "If the rules of the house were in fault, why not have reformed the rules of the house in a bolder and more stringent — "
[Mr. STORROW (telltale line): Well?]
[Time, 11.25.]
Mr. BUCK: "Now we wish very much that this state of things existed in England."
"We publish in another column."
"The actual professor is, however, a totally different person. He is mostly a modern American."
[Mr. STORROW (telltale line): Well, wait a minute.]
[Time, 11.26.]
[Mr. STORROW (telltale line): Hullo, hullo. Are you ready, are you ready, are you ready? What is it?
Yes.
Yes. Are you ready?]
Mr. BUCK: All right, Mr. Eaton.
To what is this due?
To what is this due?
[Time, 11.28.]
To what is this due?
To what is this due?
To what is this due?
To what is this due?

To what is this due?
To what is this due?
Then what is to be done?
Then what is to be done?
Then what is to be done?
Then what is to be done?
Then what is to be done?
Then what is to be done?
The first result will doubtless be to discredit the present government.
The first result will doubtless be to discredit the present government.
The first result will doubtless be to discredit the present government.
Then what is to be done?
Then what is to be done?
There is, however, another and perhaps a graver danger which the government have to face.
[Time, 11.30.]
[Mr. STORROW (telltale line): Hullo! hullo! hullo! Are you ready and listening? Hullo! are you ready? Say when you are ready.]
[Time, 11.32.]
(Speaking in the mouthpiece.)
Mr. BUCK: Harvard University finds itself in a position of considerable difficulty.
Harvard University finds itself in a position of considerable difficulty.
Harvard University finds itself in a position of considerable difficulty.
Harvard University finds itself in a position of considerable difficulty.
Harvard University finds itself in a position of considerable difficulty.
Harvard University finds itself in a position of considerable difficulty.
Harvard University finds itself in a position of considerable difficulty.
E divided by R plus R 1.
E divided by R plus R 1.
[Time 11.34.]
The dog barks.
The dog barks.
The dog barks loudly.
The dog barks loudly.
The dog barks.
The dog barks.

The dog barks.
The dog barks.
Bow-wow!
The dog barks. Do you get that?
The dog barks.
The dog barks.
The dog barks.
Stop now.

[Mr. STORROW (telltale line): Hullo. Stop now, that is the end, that is the end.]

[Time, 11.36.]

(Mr. Buck put in an *induction coil*, the primary helix of which is one fifth of an ohm resistance, the secondary of which is one hundred and fifty ohms. One cell of the same battery and the *Reis transmitter* are connected in the primary circuit. The secondary circuit goes to the line and includes the receiver, which is now a *Bell magneto receiver* of the ordinary commercial form, furnished by the complainants.)

[Mr. STORROW (telltale line): Hullo, hullo. What receiver have you got in? What receiver have you got in?

Mr. MAYNADIER: It is the Bell magneto receiver of ordinary commercial form 91,258 A.]

[Mr. BUCK: One, two, three, four, five, six, seven, eight, nine, ten. Hullo. Do you hear that?

Do you hear the make and break of the circuit?

Do you hear the noise?

Mr. STORROW (telltale line): Did you hear that? We want to know if the circuits are right? Did you hear that opening of the circuit? Do you hear the noise from opening the circuit? We want to be sure the wires are all right. (The foregoing was merely to test the electrical connections.) Hullo. Now listen. Are you ready?]

[Time, 11.39.]

Mr. BUCK (speaking on top): The horses run.
The horses run.
The horses run fast.
The horses are running.
The horses eat and drink. How do you get that?
The horses ran very fast. One, two, three, four, five.
A, B, C, D.
Six, five, three, four, two.
Am I speaking strong enough?

Six, seven, four, three, nine, two, one, five, twelve, twenty-seven, thirty-six, forty-four, ninety-five. How do you get that? Mr. Eaton, won't you tell me through the telephone whether you get that all right or not?

[Mr. STORROW (telltale line): What is it? What is it?

No, it is not Mr. Buck. What do you want to say to him?

Mr. Eaton says that he did get it all right.

Now listen.]

Mr. BUCK: Twenty-seven, sixty-three, ninety-five, forty-two, one hundred and one. I hope you got that all distinctly also.

[Mr. STORROW (telltale line): Well.

Too fast, Mr. Buck.]

Mr. BUCK: One, two, three, four, five.

The trustees of Williams College, Williamstown, Mass., received on Wednesday a bequest, I presume.

The event of the week was the formal opening, on Thursday, of the great suspension bridge across the East River, uniting New York and Brooklyn. In Brooklyn the day was made a holiday, and the business in New York was partly suspended.

(This is all on top.)

[Time, 11.42.]

[Mr. STORROW (telltale line): Now Mr. Buck is going to speak something into the mouthpiece. Please listen carefully. Are you ready?]

Mr. BUCK (speaking in mouthpiece): In Brooklyn the day was a holiday, and business in New York was partly suspended. Both the cities were decorated, the former in great profusion. In New York the exercises began at 12.35 o'clock. A review was held in City Hall Park. The ceremonies were concluded with music.

The ceremonies were concluded with music.

The ceremonies were concluded with music.

The ceremonies were concluded with music.

The ceremonies were concluded with music.

The ceremonies were concluded with music.

Do you get that all right now, Mr. Eaton?

[Time, 11.44.]

(The arrangements now are: in the transmitting room one *modern carbon microphone* instrument, to be opened presently and its exact construction shown; battery, one Grenet cell for receiver; *Reis receiver* No. 2. The instruments connected in *direct circuit* without induction coil.)

[Mr. STORROW (telltale line): Hullo! hullo! Are you ready?]

[Time, 11.53½.]

(*Mr. Eaton returns to the transmitting room and Mr. Buck to the receiving station.*)

Mr. EATON: Hullo, Mr. Buck. One, two, three, four, five, six, seven, eight, nine, ten.

I suppose if you had on a magneto receiver you could hear this all over the room, but with that one there will be more difficulty, but you will get it fairly well.

Boston, Charlestown, Somerville, New York, Chicago, San Francisco.

[Time 11.55.]

Eighty-nine, seventy-four, thirty-three, seven, six, three, ten, one.

Is that all right? Can you get what I say, Mr. Buck? Hullo! I will read to you.

Local elections held in Virginia
Local elections held in Virginia
Local elections held in Virginia
On Thursday were not
On Thursday were not
On Thursday were not
Encouraging to Mahone.
Encouraging to Mahone.
Encouraging to Mahone.
Seven counties which had
Seven counties which had
Seven counties which had
Previously given readjuster
Previously given readjuster
Previously given readjuster
Majorities went Democratic.
Majorities went Democratic.
Majorities went Democratic.

[Time, 11.57.]

(The microphone transmitter had been adjusted for talking strong right into it. *Reis receiver, No.* 2, taken off, and *Reis receiver, No.* 1, substituted for it. No other change.)

[Mr. STORROW (telltale line): Say when you are ready. Hullo, are you ready? Are you ready? Say when you are ready. Well, what is it? Are you ready?]

[Time 11.59.]

Mr. EATON: Hullo. I will read a little more to you.

The steamer "Pilot" blew up near Lakeville,
The steamer "Pilot" blew up near Lakeville,
The steamer "Pilot" blew up near Lakeville,
California, on Friday,
California, on Friday,
California, on Friday,
Eight were killed,
Eight were killed,
Eight were killed,
Seven wounded and ten missing.
Seven wounded and ten missing.
Seven wounded and ten missing.
The cause was insufficient
The cause was insufficient
The cause was insufficient
Water in the boiler.

Water in the boiler.
Water in the boiler.
The Harvard College overseers
The Harvard College overseers
The Harvard College overseers
On Wednesday postponed
On Wednesday postponed
On Wednesday postponed
The award of degrees
The award of degrees
The award of degrees
At commencement
At commencement
At commencement
Including a decision
Including a decision
Including a decision
Of the question of granting
Of the question of granting
Of the question of granting
To the governor the degree
To the governor the degree
To the governor the degree
Of LL. D.
Of LL. D.
Of LL. D.
New York, May 31st.
New York, May 31st.
New York, May 31st.
[Time, 12.02 1-2.]
May 26th, Saturday.
May 26th, Saturday.
May 26th, Saturday.
A man of business should always have his eyes open.
A man of business should always have his eyes open.
A man of business should always have his eyes open.
Chesterfield.
Chesterfield.
Chesterfield.
[Time, 12.03 1-2.]
[Mr. STORROW (telltale line): Hullo, all right.]
Mr. EATON: June 2d, Saturday.
June 2d, Saturday.
June 2d, Saturday.
Fortitude is the child of enterprise.
Fortitude is the child of enterprise.
Fortitude is the child of enterprise.

Wordsworth.
Wordsworth.
Wordsworth.
[Time, 12.04 1-2.]

NOTES OF MR. LEIGHTON, SHORT-HAND WRITER, IN RECEIVING ROOM.

Present: Mr. Chauncey Smith, Mr. W. A. Copeland, Mr. Buck, Mr. Leighton.

Instrument, Defendants' Exhibit *Reis Transmitter* in transmitting room, in *direct circuit* with *magneto receiver No.* 9 in receiving room. Mr. Buck listening. He hears as follows: —

(Time, 10.50½.) Now, Mr. Buck, did you get this all right? Halloa, Mr. Buck. (If I had a telephone, I should ask him to speak a little stronger, and I should hear all he said.)

All right. Do you understand what I say? (He doesn't speak quite strong enough. We are not permitted to give any instructions to the operator.)

1, 2, 3, 4, 5, 6, 7, 8, 9, 10. (10.54.)

(10.55.) (Little stronger.) Halloo, did you get that? Yes, now I will speak a little louder. How do you get this, Mr. Buck? 24 — 807. Do you get that all right? (with some numbers preceding, which I should have heard if I had not been talking myself.) That is a little too strong, I guess. Mr. Bradlaugh. (I understood that word. He is reading a newspaper. He has been reading a long passage from a newspaper, and I could hear occasionally a word. He was talking about Bradlaugh.) (10.59.)

(11.02½.) Halloo. Of American University — from the standpoint — of professional — causes for the present — education — cannot be. (He speaks a little too strong.) (11.04½.)

On every hand. (11.06½)

Magneto receiver No. 10 now connected. *Reis transmitter* in *direct circuit* as before. Mr. Buck hears as follows: —

(11.09½.) Halloo, Mr. Buck. 1, 2, 3, 4, 5, 6, 7, 8, 9, 10. Do you get that all right? Inefficiency — exceptional cases. (It simply breaks up. Speaking too strong.) (11.13½.)

Mr. Buck goes to transmitting room and talks into the Reis transmitter. *Mr. Eaton* receiving at magneto receiver No. 10 hears as follows: —

(11.17.) Halloo, Mr. Eaton; how do you get that? Do you get that all right? Counting. (Will you tell him that he is speaking a little too loud.) Little too loud, am I? (Too loud still.) 1, 2, 3, 4, 5, 6, 6, 7, 8, 10. How do you get that? 1, 2, 3, 4, 5 — 1, 2, 3, 4, 5 — 4, 5. How do you hear that? 1, 2 — 1, 2, 3, 4, 5, 6, 7, 8, 9, 10. Mary had a little lamb. How do you get that?

1, 2, 3, 4. Do you get that? Mary had a little lamb. How do you get that? 1, 2, 3, 4, 5. (You tell him that I have the same trouble that he did; that he is talking while I undertake to say something. While I am repeating what he said he talks, and I lose it.) Are you ready? To the editor of the *Nation*. (Repeated twice.) (He is talking too loud.) (11.26.)

(11.27½.) To what is this due? (Repeated it right over, but I could not swear to it.) To what is this due? To what is this due? What is to be done? What it to be done? What is to be done? Government. What is to be done? Government has to be. (11.31.) (11.32.) Invisible—Position—University—Considerable difficulty—University—Considerable difficulty—1, 2, 3, 4. Wait a moment. (I thought he said.) (11.35)

With *Bell magneto receiver* No. 91,258 A now substituted as receiver; *Reis transmitter* as before. Induction coil. Mr. Eaton listening, hears as follows:—

The horses run very fast. (11.39.) How do you get that?

1, 2, 3, 4, 5.

A, B, C, D.

3. 4, 5.

(I would have got the rest of it if I had not been talking.)

6, 7, 4, 3, 9, 2, 1, 5, 44, 95.

Mr. Eaton, won't you tell me, through the telephone, whether you get that all right or not?

(11.41.) 63, 95, 32, 102 (or something); 1, 2, 3, 4, 5.

Wednesday.

Opening on Thursday of the great New York — Brooklyn —

(11.42½.) The business from New York was — suspended. (There is a word between.)

(12.35) New York.

The ceremonies were concluded.

The ceremonies were concluded.

Do you get that all right now, Mr. Eaton? (11.45.)

Reis receiver No. 2. Transmitter is modern *carbon microphone*. One Grenet cell of battery; *direct circuit*.

Mr. Buck, receiving, hears as follows:—

(11.53 1-2.) Hulloo, Mr. Buck.

1, 2, 3, 4, 5, 6, 7, 8, 9, 10.

Magneto receiver — you could hear this all over the room; but with that one there will be more difficulty; but you will get it fairly well.

Boston — Charlestown — Somerville — New York — Chicago — San Francisco.

89 — 74 — 33 — 7 — 6 — 3 — 10 — 1.

Is that all right?

Can you get what I say, Mr. Buck?

Halloo, I will read to you.

Local elections held in Virginia. Local elections held in Virginia. Local elections held in Virginia.

On Thursday were not — On Thursday were not — On Thursday were not — encouraging to Munroe.

Seven counties — Seven counties which had — Seven counties — Readjuster — Previously given the readjuster — Previously given readjuster.

Majorities went Democratic — majorities went Democratic — majorities went Democratic. (11.58.)

Reis receiver No. 1 connected; *carbon microphone* for transmitter as before. Mr. Buck hears as follows: —

(11.59.)

Halloo — I will read a little more to you.

The steamer "Pilot" near Lakeville.

The steamer "Pilot" blew up near Lakeville. (Repeated again.)

California, on Friday — California, on Friday — California, on Friday.

Eight were killed — eight were killed — eight were killed.

Seven wounded, ten missing — seven wounded, ten missing — seven wounded, ten missing.

The cause was insufficient — the cause was insufficient — the cause was insufficient — water in the boiler — water in the boiler — water in the boiler.

The Harvard College overseers — the Harvard College overseers — the Harvard College overseers, on Wednesday, postponed — on Wednesday, postponed — on Wednesday postponed — the report of degrees, at the Commencement — at the Commencement — at the Commencement — including a decision — including a decision — including a decision on the question of granting — on the question of granting — on the question of granting — to the Governor the degree — to the Governor the degree — to the Governor the degree — of LL. D. — of LL. D. — of LL. D. — until May 31st — until May 31st — until May 31.

May 26, Saturday — May 26, Saturday — May 26, Saturday.

A man of business should always have his eyes open. A man of business should always have his eyes open.

(Repeated)

Chesterfield — Chesterfield — Chesterfield.

Halloo — all ready.

June 2d — June 2d. Saturday, June 2d. Saturday.

Fortitude is the child of enterprise. (Repeated three times.)

Wordsworth — Wordsworth. (12.05.)

UNITED STATES CIRCUIT COURT,

DISTRICT OF NEW JERSEY.

IN EQUITY.

AMERICAN BELL TELEPHONE COMPANY

v.

NEW JERSEY TELEPHONE COMPANY ET AL.

EVIDENCE FOR COMPLAINANTS.

TAKEN PURSUANT TO THE SIXTY-SEVENTH RULE OF THE SUPREME COURT OF THE UNITED STATES, IN EQUITY, AS AMENDED, BEFORE ME,

CHARLES H. SWAN, *Special Examiner.*

NEW YORK, Jan. 7, 1887.

Present: EDWARD N. DICKERSON, Esq., *for Complainants;*
G. P. LOWEREY, Esq., *for Defendants.*

HERMAN AUGUST HAGEN, being duly sworn, testified in answer to interrogatories, as follows: —

Direct Examination by Mr. DICKERSON.

Int. 1. What is your age, residence, and occupation?

Ans. Born 30th of May, 1817, — nearly seventy, — in Koenigsberg, Germany. Present residence, Cambridge, Mass. Occupation, Professor of Entomology at Harvard.

Int. 2. How long have you been resident at Harvard?

Ans. Nearly twenty years. Since October, 1867.

Int. 3. Were you at Stettin in Germany in 1863, and did you there witness experiments with the Reis telephone. And if so, state the circumstances and what occurred at that time.

Ans. Yes, I was at the meeting of the German naturalists in Stettin in September, 1863; and we were invited by Professor

Boettger, the inventor of gun cotton, to assist in experiments shown by him with the telephone of Philip Reis, who was sick and could not assist at the meeting. We were ushered in one corner of a large building, where the apparatus was put on a table,— very plain, very plain apparatus, consisting of a cigar box which was turned, and a piece of bladder upon, and connected by comparatively strong wires, that is, I think about two lines thick, with an apparatus placed in the most remote corner of the building. This was a large building. Professor Boettger made a short introduction in which he remarked that *that* was Philip Reis' invention, and was called "telephone,"— had the intention to transmit sounds or tunes; and that it would be valuable, for instance, and an advantage that a prominent singer in another city could be heard and enjoyed by another city.

Then Professor Boettger retired to the other room and said he would give us a transmitting of tune. I was very near to the apparatus with a dozen others, or perhaps there were twenty or thirty in the room, and we heard a rattling noise, but nobody of us could understand to be a tune. Professor Boettger appeared in our room — he was a very lively old man — and was rather astonished when they told him it was a rattling and nobody perceived a tune; and then he told us it was a very common German tune, "Ach du lieber Augustin." It is a familiar air and sung for little children; it is a tune hacked to pieces, and he had used that tune for that purpose, but nobody recognized it.

Then Mr. Boettger retired to the other room and promised to give another tune, and this time we recognized it. It was not really a transmitting of tune. It was a common German song, "So leben wir alle Tage." It is in the same hacking fashion, thus [*witness accenting*], "So *leben* wir," "So *leben* wir," "So *leben* wir." As we did know it we recognized it, but it was really no music at all; and I should compare it the only time, and that was the second time when I assisted, when Professor Bell showed us his telephone. That was in the Boston Academy and was entirely a failure, as Mr. Storrow told me, because it was somebody had disarranged the wires, and then it was the same noise I recognized that I had heard so many years ago, — which was a rattling noise, the same failure as the Bell

telephone. That was ten years ago, when I assisted at the Bell failure, and the explanation of the cause of it Mr. Storrow gave me when he called on me a few days ago. And when I told him that, he remembered that Mr. Bell had himself told him it was because somebody had disarranged the wires.

Int. 4. When was the occasion that the Bell failure occurred that you compare to the Reis failure?

Ans. The first year when he showed it in Boston. That was at Dr. Williams'; and then a few weeks later at the Academy when the failure occurred.

Int. 5. Had you heard the Bell telephone talk at that time?

Ans. Yes. Then it was, I remember, that I told directly Mr. Bell that I had assisted when I was the first time at Reis'; and that it was entirely different — that I told him — from the Bell's, because in Bell's that was speaking, and that was never intended in Reis'.

[*Counsel for the defendants objects to so much of the answer of the witness as begins with the words "because in Bell's that was speaking, and that was never intended in Reis'," being not responsive to the question, and not competent even if it were responsive*]

[*The witness continuing:*] What I state here as bearing on my presence on Sept. 19, 1863, is what then was stated in newspapers; and what has been in later years done I have not seen. If something else has been printed, that I could not know; but as I was present with these things, saw them, I believe I would have known it; and that I never heard that it was intended to speak, but only intended to transmit tunes. That it was what Professor Boettger told us, and it was in all newspapers at the time, which I possessed, but I am sorry, I think I have thrown away before I left home; was never spoken of that it should be spoken. If that is later done, that I cannot say; but I state only what I know.

Int. 6. Have you with you a German journal giving an account of the meeting at which you were present?

Ans. Yes, sir [*witness produces book*], this is a special report of the meeting of the German naturalists in Stettin in 1863, printed in 1864. There is on p. 149 a statement that on Saturday, Sept. 19, Professor Boettger in the room of the chemical section showed experiments, a telephone constructed by Professor Philip Reis.

That is all. And the same is repeated in the daily report, p. 18, of the same book. I remember that very full reports were given in one, at least, and perhaps in two daily papers in Stettin. I have them not now, and could not tell anything more, than what I have told.

Int. 7. Did you at that time, or at any time before you left Germany, hear anybody say that that Reis telephone was a speaking telephone?

Ans. No.

[*Counsel for defendants objects to the question and answer as calling for negative and incompetent testimony.*]

Int. 8. What was your professional occupation at that time?

Ans. I was physician, and besides, naturalist in my free time.

Int. 9. And as naturalist you attended that meeting?

Ans. Yes, sir.

Int. 10. Will you state how the information which you are now giving us came to be communicated to Mr. Lyon of Washington and why?

Ans. I was in Washington about three weeks ago, when I was looking for copies of patents to Chichester Bell to send to my nephew in Germany, and there accidentally met Mr. Lyon, who was a friend of a friend of mine, in Washington, and talked about the telephone, when I informed him of the matters to which I have testified here.

Int. 11. Then afterwards when you returned to Cambridge, who came to see you about it?

Ans. Mr. Lyon telegraphed to know whether I would be at home; and later wrote me a letter that he could not come, and that Mr. Storrow would see me; Mr. Storrow came and saw me in the Museum.

Int. 12. On the two occasions at Williams' and at the Boston Academy of Sciences when you saw the Bell telephone, about ten years ago, at which of them was the exhibition a failure, and at which did the telephone talk?

Ans. At Williams' it was a success and the telephone talked; and at the Academy it was a failure.

Cross Examination by Mr. LOWREY.

Cross-Int. 13. Did Professor Bell say on the occasion when his telephone failed to transmit, that it was because of any difficulty in the wires?

Ans. He did not say anything that evening; it was after ten o'clock and we were tired out.

Cross-Int. 14. How long had you been engaged before ten o'clock trying to hear something by Professor Bell's telephone at that time?

Ans. Not at all.

Cross-Int. 15. The experiment was therefore made at ten o'clock, and not succeeding, there was no renewal of it?

Ans. No.

Cross-Int. 16. What did Professor Bell, or any one, try to transmit by his telephone that evening, if you know?

Ans. I do not know.

Cross-Int. 17. You did not hear?

Ans. No.

Cross-Int. 18. The noise which you heard was at the receiver?

Ans. Yes.

Cross-Int. 19. Do you know whether what is called in this country the receiver, that is, the part at which you listen, is also called the receiver in Germany; or do they call the part to which you speak, the receiver, in Germany?

Ans. I cannot tell.

Cross-Int. 20. Will you describe more fully the kind of noise which you heard at the Bell receiver; give it a name.

Ans. A rattling noise.

Cross-Int. 21. What was the character of the noise which you heard at the Reis receiver?

Ans. Also a rattling noise.

Cross-Int. 22. As nearly as you can remember, were these noises about identical in character?

Ans. Similar. That is the only reason I spoke about the thing. It was so similar that I remember remarking to one sitting by me, "That is the same that I heard by Reis." That is all.

Cross-Int. 23. On the occasion of the Reis experiment, how were the wires conveyed from the room where the transmitter was placed to the room where the receiver was placed?

Ans. Along the corridors and through the open doors in a very primitive manner.

Cross-Int. 24. Were the wires in the case of the Bell experiment conducted in the same manner?

Ans. Yes. If you know the Academy, there is a front room that is connected with the large rooms behind that do not belong to the Academy. Permission had been given to Mr. Bell to put his apparatus in it, and it was through the doors, and only for that evening.

Cross-Int. 25. When did you first see Mr. Storrow on this subject?

Ans. After I came from Washington; within a few days past.

Cross-Int. 26. When you first saw him did you tell him of the failure you had witnessed in the Bell transmission?

Ans. Yes, sir, to compare the reason of the noise.

Cross-Int. 27. And did he then tell you, or at some later time, that that failure was attributed to some trouble with the wires?

Ans. Yes, sir; at that time he told me that somebody had disarranged the wires.

Cross-Int. 28. Did he at that time say that he was present and personally knew of the disarrangement of the wires?

Ans. No.

Cross-Int. 29. Did he tell you how he came to be informed that the wires were disarranged?

Ans. He said Mr. Bell told him.

Cross-Int. 30. Did he tell you when Mr. Bell had told him?

Ans. No.

Cross-Int. 31. Did Professor Boettger express astonishment, in words, when he returned and found that you did not recognize the tune?

Ans. Yes, sir.

Cross-Int. 32. Did he say that he had had any previous experimenting with this telephone in which tunes had been transmitted and recognized?

Ans. Certainly.

Cross-Int. 33. What did he state on that subject?

Ans. Twenty-three years after, what shall I say of my impression? I can only say of impression, at first, of course; he said he had brought it over because Reis could not; and that he had heard tunes transmitted, but I could not tell you what more.

Cross-Int. 34. You mentioned something about Philip Reis being ill and not being present on that occasion; state what was said in respect to his illness by Boettger.

Ans. Boettger stated only that he was ill and could not come.

Cross-Int. 35. You mentioned that the apparatus consisted of a cigar box, and you mentioned a bladder in connection with it. How was the bladder connected?

Ans. It was laid in a circular hole.

Cross-Int. 36. What part of the instrument containing the bladder and the circular hole did you apply to the ear to listen?

[*Counsel for plaintiff objects that the witness has made no such statement.*]

Ans. I was near the apparatus, and we were only standing round the instrument. [*Indicating about two feet.*]

Cross-Int. 37. Are you sure, Professor Hagen, that you are not confounding the instrument which was used for sending with the receiver?

Ans. Quite sure.

Cross-Int. 38. Did you see the instrument which was employed at the transmitting end?

Ans. Yes, sir; I went to that room.

Cross-Int. 39. Will you describe that instrument?

Ans. I will tell you, that is a queer thing after so many years. It was, as I remember, a similar cigar box; and there was probably an armature with a horseshoe magnet, and perhaps a few battery cells; more I could not tell. It was even as simple and cheaply constructed as the other.

Cross-Int. 40. You think you saw in the transmitting instrument a magnet, — a horseshoe magnet?

Ans. I think so, but I would not say; it is after so many years.

Cross-Int. 41. What kind of an apparatus was the Bell apparatus which failed?

Ans. His first apparatus a box that I have seen in Washington. More I could not tell you.

Cross-Int. 42. Do you understand the difference between Mr. Bell's magneto telephone and what is called the variable-resistance telephone?

Ans. No.

Cross-Int. 43. Do you understand whether the instrument in use was the instrument subsequently used at the Centennial, or any other public exhibition?

Ans. I could not answer that question. I know nothing more than that it was his first telephone.

Cross-Int. 44. How long did the exhibition, or experiment, last under the auspices of Professor Boettger?

Ans. You may say, after all, not an hour.

Cross-Int. 45. And there were about forty persons present to listen?

Ans. Yes. That was, they came in and went out. I will say between thirty or forty who witnessed it. Certainly not more.

Cross-Int. 46. Did you remain during the whole time?

Ans. Yes, sir; because I was very curious, and had never heard before anything like it.

Cross-Int. 47. Do you mean you had never heard anything before about the Reis telephone?

Ans. No; personally not.

Cross-Int. 48. Did Professor Boettger say anything about whether the instrument would, or would not, transmit articulate speech?

Ans. He said nothing.

Cross-Int. 49. What he said was, as I understand you, that it was an instrument to transmit sounds or tunes?

Ans. Yes, sir.

Cross-Int. 50. Can you remember the German term — I do not ask you now what would be your present translation — in which he said what would be transmitted?

Ans. "Melodie."

Cross-Int. 51. And when he said sounds, what was the term he made use of?

Ans. "Tone."

Cross-Int. 52. Tunes would be the equivalent of "melodie" more than of "tone," would it not?

Ans. Entirely.

Cross-Int. 53. Sound for "Tone," and tune for "Melodie"?

Ans. Yes, sir.

Cross-Int. 54. He made use of both those terms, as you remember?

Ans. Yes, sir. Of "Melodie" I am very sure; of the other also, but I would not state that on my oath.

Cross-Int. 55. You have intimated that Professor Boettger selected the tune to be transmitted because of some peculiarity in it which you call "hacking"? I understand you to mean a peculiar accentuation. Did he tell you he had selected it for that reason?

Ans. Yes, sir.

Cross-Int. 56. As nearly as possible, recall his words, and state them, when he told you he had selected the tune for any particular reason.

Ans. I cannot do it. That would be my own, if referred to.

Cross-Int 57. Are you quite sure then, Professor, that he told you that, or did you not infer that from your own knowledge and information?

Ans. No; he told it.

Cross-Int. 58. You say you told Professor Bell that you had witnessed a similar failure with the Reis instrument?

Ans. No; I did not say that. I only said that I assisted at the Reis; and that it was very different from his, because it did not speak.

Cross-Int. 59. On which occasion did you tell him this?

Ans. It was the first time I saw him, at Dr. Williams', when he showed us the first time he experimented at the Thursday Club; that was the first time, when he succeeded. Dr. Williams is a professor of Harvard.

Direct Examination by Mr. DICKERSON.

Int. 60. You spoke of Dolbear just now. When did you have any communication from Professor Dolbear on the subject, and what did you tell the person who came to see you?

[*Counsel for defendants objects:* First, *that the testimony now called for is not responsive to anything brought out in the cross examination under questions of the counsel; and* Second, *that conversations, admissions and communications of any sort between Professor Dolbear, or any representative of his, cannot be binding upon the defendants, and are therefore incompetent, irrelevant and immaterial.*]

Ans. I never had any communication with Dolbear. Of course, he is a member of the Academy, as I am, and so I have seen him there. Probably he knows me, as I am well known there; but I have never had any communication with him.

I think it may be seven years, I cannot say, when a lawyer, whom I do not know, called upon me. I suppose it may be Mr. Stetson, but that is only a suggestion, came to see me and asked me about the things. I showed him the official report, and told him I had been present at the Reis exhibition, and that it did not speak, and was not intended to speak; and that is all. Then he left me, and I think three or four years later he came again. I did not recognize him at this time. When he first came I had never seen Dolbear. Then he asked me again, and I told him again what I knew, and gave him an introduction and perhaps the names only of the persons in Frankfort and Stettin where he could get perhaps the daily papers, and files, and see the description, because I said I could not tell him more, and he was satisfied. Two of the names I gave him were Lucas von Haydn, and my friend, Dr. Dohrn, in Stettin. If he would apply there perhaps they would be able to find out for him the daily papers. I never saw him more, — cannot tell you who he is. It was a small man with pale blond hair — young man. He was both times in the Museum; and the second time he had to remember me again, because I had entirely lost that he had been there before. Professor Dolbear I have sometimes seen in the Academy; do not remember his looks; I would not recognize him at all; certainly never spoke a word with him; he resides near Cambridge.

Int. 61. I now show you a diagram contained in Reis' letter to Ladd on the 7th of August, 1883, at p. 44, of a pamphlet in this case, entitled "Reis and Bourseul Publications," and ask you whether that diagram refreshes your memory as to what you saw at Stettin in 1863?

Ans. This certainly [*indicating the receiver*], because I know it was what we called a knitting pin put through a coil of wire. That I saw. The other one [*indicating the transmitter*] is more elaborate than I had in my idea. I could not tell you anything more.

Int. 62. The knitting needle receiver, then, is what you intended to describe when you used the word "armature" and "horseshoe magnet," is it?

Ans. This I can identify. I had an idea a magnet was in the other [*pointing to the transmitter*], but that I do not know.

Cross Examination by Mr. LOWREY.

Cross-Int. 63. You have said that the apparatus which you have heard when at the Boston Academy was Mr. Bell's first apparatus. Do you mean to adhere to it that it was his first apparatus, or are you acquainted with the order and series of his different apparatus?

Ans. I have seen a number of them, but it was only that I was told that it was the first apparatus. I could not identify it. I have seen Mr. Bell's experiments very often, shown me by Mr. Bell.

DR. HERMAN AUGUST HAGEN,
Professor of Harvard University, Cambridge, Mass.

JAN. 8, 1887.